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Plastics

Dealing with the Manufacture, Uses and Potentialities of Plastic Materials

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NOTICES

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SAVE PAPER

More than ever is paper waste required for our war industries. Waste paper makes munitions in a hundred forms—from shell cases to aeroplane parts.

The fact that goods made of raw materials in short supply because of war conditions are advertised in this journal should not be taken as an indication that they are necessarily available for export.

EDITORIALS

Dangerous Moonshine

WE are, let us face it, on the horns of a dilemma. It is little more than three years ago that most of us in the plastics industry would have given our very eye-teeth for good publicity about the things we produce, for the daily Press of the country can make or mar much. To-day the plastics industry is in the position of almost fearing the best of publicity lest it be misunderstood.

There has been much good propaganda and some straightforward reporting, but the spate of nonsense written and spoken in the past year about plastics has so flooded the country that we stand in danger if not of drowning at least of getting thoroughly wet and dangerously feverish. To the non-thinking journalist all aeroplanes are made of plastic green cheese and that even 1,000 h.p. engines can really be made of this " bakelite stuff " if we only tried hard enough. Ships (10,000 tonners are inferred by implication) and bridges, staircases and gearwheels can be made from " literally nothing " and for " next to nothing." The strange self-deception that plastics are cheap still pervades the air of this roseate dawn of the so-called plastic age. We may yet rue the day that we smiled benignantly on those who declared it such, and promised the world a life and death of plastic toys and plastic coffins.

Here and elsewhere we have resented always this phrase as being particularly dangerous. It is a specious phrase, meaning nothing, lending glib force to a more specious argument.

Bricks—And How to Drop Them

The height of misleading and exaggerated statements was reached in the " ' Star ' Man's Diary " of November 17, and we reproduce his words at length. He tells of a so-called interview with a Dr. H. A. Skinner:—

" Dr. H. A. Skinner, the scientist who predicted a sort of ersatz age after the war, when he presided over a London conference of chemists arranged by the Association of Scientific Workers, was in bed with an old-fashioned cold when I talked with him to-day.

" I imagined him drawing the non-ersatz bedclothes closer round his chin as he drew for me a picture of the revolutionary changes that may or may not make the world a happier place to live in.

" Dr. Skinner is convinced that houses will be built to last only 10 years at most, that clothes will be moulded to the body and not tailored in the usual way, and that laundries will be unnecessary because all wearing apparel will be cheap enough to be scrapped once it is dirty.

" ' We must make the most of the war,' said Dr. Skinner, ' and turn to civilian account all the fruits of scientific research. The last war brought to the front the aeroplane, the motorcar, and wireless.

" ' Plastics are the thing in this war. Already we make stockings from nylon, and almost anything in light clothing can be produced from this substance.

" ' Plastic clothes can be moulded to the body; there need be no cutting and shaping and fitting. Instead of a man wearing a suit for, say, a couple of years, he will use it only for three months, and then throw it into the communal dustbin for remaking.'

" Dr. Skinner paused a moment to dream. ' We build everything,' he said, ' to last 200 years—and what a mistake! Cars, for instance, are just a memory after 10 years and hopelessly out of date. Houses are like that, too. Plastic bricks will enable anyone to change the shape of his house at any time.' "

" . . . I left the Doctor dreaming."

If this be an accurate report what can one say of Dr. Skinner's profound knowledge of tailoring, building, plastics and economics? This scientist does not yet know that the ancient clay brick is made of a perfect plastic and that it is a perfect unit for making any shaped house we choose. The Doctor was not only

dreaming, he was in the throes of a horrid nightmare; and what is worse—he was talking in his sleep.

We call this and similar reporting of the plastics industry dangerous because of the completely false picture it gives of the world, and what is more important, of the exaggerated hopes that many readers of it may place in the plastics industry.

Such exaggerations are made not only by journalists who lack an appreciation of chemical and engineering technology, or by youthful scientists who should know better. Quite recently Professor Inglis, one-time president of the Institution of Civil Engineers, stated that progress in engineering would lie mainly in the production of plastics and that iron and steel would be reduced to a position of secondary importance. If we realize that in peace-time the world production of crude steel is about 140,000,000 tons, while the present war-time world production of all plastics is probably under 600,000 tons, we can get an idea of the time lag before Professor Inglis's prophecy comes true.

Already we are receiving numerous inquiries from youths and men in the Army, Navy and Air Force asking how best they can get into the new plastics industry which offers so much to them, and it is not very agreeable to throw cold douches on our modern inquiring and energetic youth, who, after finishing the most dangerous jobs of their lives, will want to settle down to peace-time working.

The plastics industry is a remarkable industry and a very wonderful one, throwing its tentacles into almost every branch of life. But it is still young and, being based on sound scientific principles of chemistry, physics and engineering, its progress must, for its health's sake, be gradually developed, each step being carefully examined scientifically and controlled as it is made.

There are great openings for youth and, indeed, the industry, as Mr. Kenneth Chance showed last month, is anxious to open its doors to the proper type, but such youth must realize that, like any other scientific endeavour, the process of learning the fundamentals in whatever branch of plastics is undertaken, is as slow and as hard as those of any other industry. This being said, we may add that finality may never be reached in plastics and in a strong sense it is to the new chemist, new physicist, new engineer and new artist designer that we look for even greater improvements.

The other and more insidious danger resulting from careless talk is the attraction the new " plastics age " may have for the financial adventurer who sees in it a chance to play upon public gullibility and launch so-called industrial structures with no fundamentally sound bases.

Synthetic Rubber

OUR readers will have gathered from our past history that we in this journal are advocates, to put it mildly, for the manufacture of synthetic rubber in this country, and, as a corollary, for the manufacture of carbide, the cracking of petroleum, or any other process in any raw material which might be entailed. As one of our friends put it, we nearly threw a fit when Mr. MacMillan, of the British Government, told the country some eight months ago that Great Britain would make no synthetic rubber and that the United States of America, with its large supplies of petroleum, is the logical place where synthetic rubber should be made and that she would ship it to us.

Our own words at the time were: " MacMillan has handed Great Britain's technical future to the U.S. on a bejewelled golden plate," which, although they were spoken through a red haze, did not greatly exaggerate the whole position.

Last month Mr. Oliver Lyttelton, Minister of Production, said, in replying to a question, that he was satisfied that he possessed adequate information regarding processes and inventions for the production of synthetic rubber and that he was therefore able to judge what would be the most appropriate process to establish production in this country. We are

pleased that he now has sufficient evidence in front of him. What is more important is, will he carry this judgment into practical effect?

What caused this volte face is, no doubt, due to the committee of scientists and technologists he set up as a result of the storm of protests that arose. We are glad that the efforts of certain M.P.s, among them the vigorous Mr. Parker, to whom we had the pleasure of putting our views on the subject some six months ago, have had the desired effect of making the Government think again.

One wonders, however, why the advice of experts was not sought earlier, and we are left with the conclusion that false political and international argument had had its way. We know it had been bruited abroad that the production of carbide (not necessarily for plastics manufacture) was out of the question because of the shortage of coal. There undoubtedly was a shortage, but that this existed, and still exists, is a direct reflection on the Minister of Production. Lack of foresight and lack of organization must be laid at his door.

Our main argument, however, was that not only would knowledge and foresight before the war of the importance of synthetic rubber and rubber-like plastics have prevented the present state of our rubber industries, but that, as important as our food, the technical genius of this country must not be frittered away.

This country, whatever the future, will always be an industrial one dependent on the training of our youth in all branches of technology. The plastics industry is becoming one of the most important and that branch of it known as high polymer technology is of fundamental application. Cost of raw material matters but little in the final analysis. It is the genius behind the industry that matters and the fact that petroleum or other raw material must be imported matters not one whit.

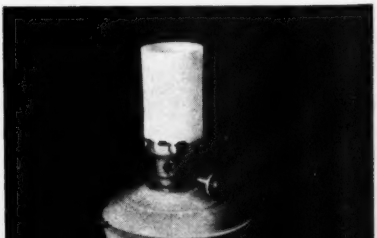
The British people have a horrible habit of believing that other countries have the chemical and physical brains. In chemistry, anything German was best—a piece of brilliant propaganda put out by Germany far better than anything done by Dr. Goebbels. This idea was exploded sky-high during the last war and after, with respect to dyestuffs, of which we now manufacture 100 per cent. of our own big consumption. It is being exploded with respect to medicinal products, plastics, and many other products.

We must be allowed to produce any product we wish if we can do it well and economically. Give us the chance and we will produce the goods—the tools we can make ourselves.

Light Plastics in Dark Places

WE had had the small oil-lamp, shown below, in our possession for a considerable time before we realized that the "chimney" was made of translucent Beetle. Association of ideas, we presume, since only one material has ever been used for the purpose and that it must be glass because of the flame. In point of fact (the lamp is a small night-light) the flame is so small that the "chimney" never gets hot and the job is better carried out in plastics than in glass, because of its resistance to breakage.

We had thought at first that the tube was an extruded one. This is not so; it is moulded. The lower diameter is slightly smaller than the top, to assist moulding. No doubt the base could also be made from the same plastic, which is oil-resistant, although it would necessarily be weighted with metal for balance.



FORMVAR BOND *for Airscrews*

New technique in the fabrication of Hydulignum airscrews entails the novel use of polyvinyl resins (e.g., Formvar), and the application of two-way compression to obtain a highly homogeneous material of controlled density.

SYNTHETIC resins of the phenolic type have been employed as a veneer bond for the construction of airscrews for some years. The use of resins of the thermoplastic type is, however, a new adoption, and it is interesting to note that British engineers are foremost in this production, which is having an important effect on the performance of our fighter aircraft.

Hydulignum is the name of the new wood structural material and is the only form of bonded laminations used for airscrew construction utilizing a thermoplastic resin. The manufacturers and inventors of Hydulignum—the Hordern-Richmond Aircraft Co., Ltd.—chose Formvar, the well-known derivative of polyvinyl acetate, made by Shawinigan, Ltd., as having the most suitable properties for their purpose. These are (1) high softening point, important in the tropics, (2) lack of brittleness at low temperatures indicating resilience under freezing conditions, (3) extreme toughness and durability.

Method of Production

Birch wood veneers, each originally 1-36 in. in thickness, are coated with Formvar solution, weighed in packs (about 60 to a pack) and then consolidated under heat and pressure. The density of the material produced in this first operation is controlled to 60 lb. per cubic ft. It has been found that any pressure beyond this point results in spreading of the veneers and consequent loss of strength and density control.

By a second operation, the material is retained under heat and pressure on the top and bottom surfaces, while side pressure is introduced to increase the density by the required amount, which can be as high as 80 lb. per cubic ft. This two-way compression produces a more homogeneous material, and it is preferable to use a thermoplastic resin which enables the material to be made in two operations giving a closer control of density than is possible with any other material. This is a most important characteristic of Hydulignum, reflecting on the ultimate balance of the blade.

The material is particularly stable and blocks can be left for an almost indefinite period without deterioration. It is also easier to machine than other high-density materials.

The two-way compression has the added advantage that if any reaction should take place due to shrinkage or expansion under extreme conditions, this is equal in both directions and, therefore, does not result in ovality of blade root.

Another important feature is that veneers of inferior quality can be used entirely without detrimental results.

Root Attachment: Diameter of Adapter

This is one of the most important factors in considering multi-bladed propellers, and is governed by the shear strength of the material on the internal thread of the adapter. With all high-density wood materials which are compressed in one direction only, the shear values taken on the face of the board are considerably lower than those taken along the edge of the board. When, therefore, calculating the minimum root diameter from available shear strength, the lower value must be taken in each case.

In Hydulignum, the material is compressed in two directions, and by exhaustive investigation into varying degrees of compression in each direction, a perfect balance of shear has been obtained, giving a relatively higher value and consequently permitting considerably smaller root sizes.

The conclusion drawn from tests is that

Hydulignum propeller blades can be made with considerably smaller root diameters than those generally adopted at present.

This has already been proved by a recent adaptation for the replacement in Hydulignum of hollow steel blades fitted to the Curtiss Electric propeller (No. 1½ size) and successfully flown on American aircraft. In this case, the actual steel blade root has been used as an adapter, threaded internally to take the Hydulignum blade.

The duralumin blade designed to give equal performance on this aircraft can be fitted only to the No. 2 size hub, owing to the necessity for a larger shank size on this type of blade than on the steel blade, and the fact that the Hydulignum blade root has been fitted inside the steel blade root has shown that still further reductions in root diameters can be made.

With the introduction of four or more bladed propellers to absorb greater engine powers, limitations on blade root sizes present one of the greatest problems and it is evident that propellers can now be designed to use Hydulignum blades where no other type of wood or even metal can be considered.

With the object of reducing this root size to a minimum, beyond present-day conception, Hordern-Richmond Aircraft Co., the makers of Hydulignum, have devised a special adapter, using an internal-threaded plug screwed into the end of the blade and locked to an external sleeve of opposite thread. It has been found, on test, that the shear on the blade root can thus be increased in proportion to the threaded area.

Blade Stiffness

The stress allowances on Hydulignum enable the thinnest sections to be used throughout the blade, and the frailty of tip sections is minimized by the absence of brittleness in the material.

High-density blades can be produced with plant of comparatively small capacity, owing to the small area of the sides of the boards to be compressed.

The two-way compression also gives greater stiffness. and as it can readily be used throughout the length of the blade, it would appear that Hydulignum offers possibilities in blade design greater than any so far envisaged for wood or metal.

The resilient properties of the Formvar resin should tend to damp out vibration or tendency to blade flutter.

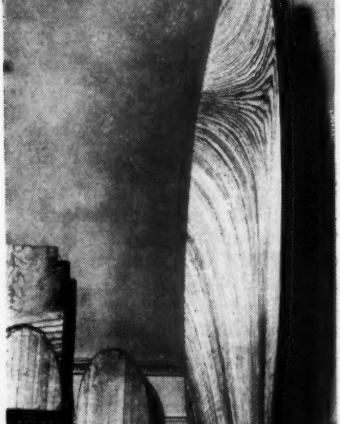
Blade Balance

The manufacturing process of Hydulignum has been carefully devised to ensure the closest possible density control which has enabled all blades of one design to be made interchangeable.

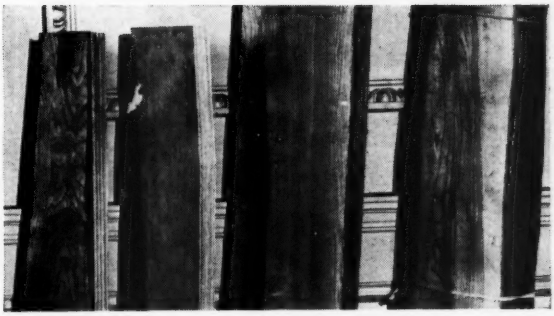
This has been carried still farther by the inclusion of those blades returned to the factory for major repairs.

Other types of wood blades are balanced either by individual sets or to two or three standard masters and marked accordingly. This practice complicates the spares problem, particularly in units operating overseas.

Complete interchangeability has been



Finished Hydulignum blade ready for the outer protective coating.



The four main processes of producing plastic-bonded Hydulignum. Extreme right: the birch veneers treated with Formvar. Next is the bonded board. Inner, left, the material is seen after the side pressure has been applied. Extreme left, a Hydulignum airscrew lamination is shown with the root portion tapered.

maintained with Hydulignum blades by means of the uniform density of the material which allows all blades to be balanced to one master within dimensional tolerances.

In order to attain perfect dynamic and aerodynamic balance which is most desirable in blades designed for high-speed aircraft, it is necessary to restrict these tolerances to a minimum and call for the closest dimensional accuracy. This is possible with Hydulignum blades by the attachment of a simple balancing device to the root of the blade. By this means, all blades can be shaped to size, eliminating the time at present required for correcting balance, both in shaping and covering.

The root of the blade is bored and fitted with a bush to accommodate the weight for horizontal balance. This bush can be threaded and used as a plug.

Vertical balance is obtained by lead quadrants which can be adjusted to give any desired correction without alteration of the mass.

This balancing device has been tested and proved to give very satisfactory results, while the boring and bushing of the blade root has the added advantage of reducing the possible shrinkage of the material referred to above, without any loss in shear strength.

The effect of this adaptation on other materials is not known, but it is believed that their densities are not sufficiently controlled to obtain interchangeability and perfect balance by this means.

The following figures show the mechanical properties of Hydulignum:—

Specific gravity ...	1.31 (82 lb. per cubic ft.)
Tensile strength ...	45,700 lb. per sq. in.
Compressive strength	21,000 lb. per sq. in.
Shear L.T. ...	4540
Shear L.N. ...	4480
Modulus of elasticity	4×10^6 lb. per sq. in.

Acrylic Resins in Dentistry Film

NOW that 90 per cent. of the world's rubber is in enemy hands, acrylic resins have become of immediate interest to all dentists. Imperial Chemical Industries has just completed a film showing the technique of processing an acrylic resin denture base. The film emphasizes that these resins are far more than a substitute for the now unobtainable vulcanite.

Starting with the dental surgeon taking a wax impression in the usual way, the entire operation is demonstrated—the mixing of a typical acrylic resin denture base; packing it into the mould; hardening, deflasking and finishing, showing that the latter process is identical with that used in vulcanite. Final sequences deal with the technique of special cases, repairs, cleaning and porosity.

Both sound and silent versions will be available in sub-standard (16 mm.) size, running time being 30 minutes. Distribution will be through the professional associations, medical schools and the Central Film Library of the Ministry of Information.

Goggles for Industrial Hazards

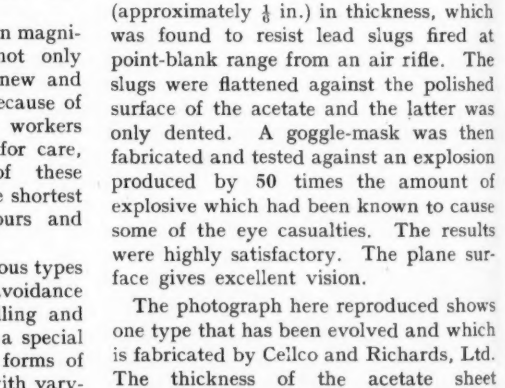
AMONG the commonest and most serious accidents that occur in modern industry are those that affect the eyes. In peace-time the danger was sufficiently great: in chemical works where the worker may be exposed to acid, alkali and other chemical splashes, in steel grinding and metal working generally, and in a wide variety of factories where carelessness or the lack of suitable protection may result in major or minor accidents to the eye.

In war-time the danger has been magnified to an enormous extent not only because of the introduction of new and dangerous industries, but also because of the rapid introduction of new workers not imbued with the necessity for care, the commendable attitude of these workers to increase output in the shortest time, work during unusual hours and general strain.

In the case of the more dangerous types of work which war entails, the avoidance of accidents to eyes in shell-filling and other explosive works has been a special field of examination. Various forms of eye-goggles have been devised with varying degrees of success. More recently a special type for such work, where even small explosions may easily result in loss of sight, has been devised and patented by H. J. Smith, F.B.O.A., who has acted as supervising optician at one of the large Royal Ordnance Filling Factories.

One of the important disadvantages of many types is the cutting off of the field of side vision and of undue weight, with the result that fatigue often forces the worker to discard the goggles temporarily or to shift them to the forehead, thus increasing the incidence of danger. The inventor has produced a new design with the object of providing a very protective type which, at the same time, is free from curtailment of vision and free from distortion. His first experiments were with a sheet of cellulose acetate 4 mm. (approximately $\frac{1}{6}$ in.) in thickness, which was found to resist lead slugs fired at point-blank range from an air rifle. The slugs were flattened against the polished surface of the acetate and the latter was only dented. A goggle-mask was then fabricated and tested against an explosion produced by 50 times the amount of explosive which had been known to cause some of the eye casualties. The results were highly satisfactory. The plane surface gives excellent vision.

The photograph here reproduced shows one type that has been evolved and which is fabricated by Cellco and Richards, Ltd. The thickness of the acetate sheet employed is about that indicated above, but other thicknesses are available. As the goggles weigh as low as 2 oz. they can be worn without fatigue.



The new type of industrial goggle-mask described above.

Pliable Plastic Tubing in Production

With special reference to polyvinylidene chloride, the new resin made by the Dow Chemical Co.

By H. W. PERRY

TUBING that is suitable for use in place of metal and rubber tubing in many industrial processes, plumbing and transportation applications, is being produced in seamless continuous lengths from a synthetic plastic newly developed by the Dow Chemical Co. in the United States. The company states that it is coming into extensive use to replace tubing made of such strategic materials as copper, stainless steel, nickel and rubber for the transmission of gases, liquids and chemical suspensions.

This new type of tubing is produced commercially for military and essential civilian requirements by a number of licensed fabricators from raw plastic material supplied by the Dow company and identified by the registered trademark name Saran. The material is a thermoplastic formed by co-polymerization of vinylidene and vinyl chlorides and is extruded hot up to 375 degrees F. from a specially designed tube-forming machine in any desired lengths. Sizes at present available range from $\frac{1}{8}$-in. to $\frac{3}{4}$-in. outside diameter, with various wall thicknesses from 0.031 in. to several times this section.

Flare-type fittings, such as tees, elbows, couplings and adapters, injection moulded of the same material in designs slightly modified from standard S.A.E. metal tube fittings, also are available from moulders equipped for producing them from Saran. Use of these fittings with the tubing in a complete system provides a plastic seal at the joints which avoids liability of leakage through unequal expansion of metal fittings and

Table 1.—Some Properties of Saran Plastic Tubing

Specific gravity	1.68 to 1.75.
Specific volume, cubic in./lb. ...	15.8 to 16.6
Clarity	Translucent to opaque
Colour possibilities	Extensive
Effect of sunlight	Darkens slightly
Burning rate	Self-extinguishing
Melting point	155-163 degrees C., 310-325 degrees F.
Extrusion temperature	Up to 190 degrees C., 375 degrees F.
Injection moulding temperature ...	149-204 degrees C., 300-400 degrees F.
Resistance to continuous heat ...	Up to 80 degrees C., 175 degrees F.
Distortion temperature	66-82 degrees C., 150-180 degrees F.
Coefficient of thermal expansion, per degree C.	15.8 × 10 − 5
Machining qualities	Good
Tensile strength, ultimate, lb./sq. in.	4,000 to 6,000
Elongation, ultimate, per cent. ...	15 to 25
Compression strength, yield point, lb./sq. in.	7,500 to 8,500
Flexural strength, lb./sq. in. ...	15,000 to 17,000
Impact strength, $\frac{1}{2}$ × $\frac{1}{2}$-in. notched bar, ft.lb./in. notch, Izod ...	2 to 8
Hardness, Rockwell	M38, superficial 15Y 71
Fatigue resistance	Excellent

plastic tubing and also results in uniformity of physical, chemical and electrical properties throughout the system. Metal fittings may be used, however, without affecting the tubing.

Saran tubing is described as tough, strong, flexible, non-corrosive, non-scaling, chemically resistant, non-flammable, odorless and non-toxic. It withstands high and low pressures, including freezing of contained liquid without bursting, and heat up to 175 degrees F. Various properties of the tubing are given in Table 1.

Compared with copper for service conditions, it is superior for handling salts, acids and bleaching agents, equally good for air, water, oil and solvents, but not recommended for some chlorinated aromatic hydrocarbons and certain oxides. It is pliable at temperatures above 70 degrees F., but stiff and brittle at low temperatures, melts at 310 to 325 degrees and is not recommended for use where temperatures are or may be above 170 degrees F. Thermal and electrical conductivities are low and resistance to vibration and fatigue is high.

Bursting pressure and recommended working pressure (with a safety factor of 5) increase rapidly with decrease of temperature from 100 degrees C. (212 degrees F.) to 0 degrees C. (32 degrees F.), then remain approximately constant to − 40 degrees F. Resistance to internal pressure rises more sharply with temperature reduction as wall thickness is increased, as shown in Table 2 and Fig. 1. This enhancement of bursting strength is accompanied, however, by a corresponding reduction of impact strength as temperature is lowered from 25 to 0 degrees C.

Table 2.—Bursting and Recommended Working Pressures

At room temperature of 25 degrees C. (77 degrees F.).

Tubing dimensions.		Pressures.	
Outside diam.	Wall thickness.	Bursting.	Working (safety factor of 5).
in.	in.	lb./sq. in.	lb./sq. in.
1/8	0.031	1,900	380
3/16	0.031	1,250	250
1/4	0.031	900	180
1/4	0.045	1,350	270
1/4	0.062	1,900	380
5/16	0.031	700	120
5/16	0.062	1,700	340
3/8	0.031	575	115
3/8	0.062	1,250	250

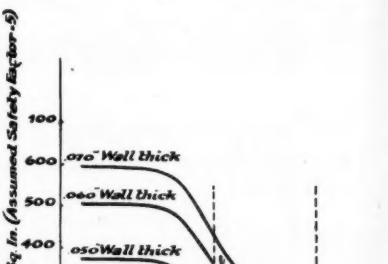


Fig. 1.—Temperature/pressure chart for Saran.

The tubing can be bent and formed readily at room temperature, and cut and trimmed with a sharp tool or file. To obtain a permanent bend or flare, it is bent or flared 20 to 30 per cent. in excess of the desired shape to allow for spring-back, then heated to 100 degrees C. (212 degrees F.) for 15 to 30 secs. and allowed to set by cooling. The heating can be done conveniently in boiling water or in steam at atmospheric pressure. Flaring is best done with compression-type flaring tools or by spinning.

Bends of a radius only three to six times tube diameter can be made without kinking, using no internal support, and the thicker the wall is the less the tendency is to kink. Permanently set elbows, traps, nozzles and the like having an inside bend radius as small as one-half the tube diameter can be made by filling the tubing with fluid and following the same procedure.

Polyvinyl Acetate Adhesives

The Author discusses the physical character and the behaviour of these now widely used adhesives under test conditions of varying humidity and temperature

By
E. E. HALLS

IN a previous article in "Plastics," June, 1942, p. 183, some attention was given to vinyl adhesives of American origin. In particular, their merits as air-drying jointing media for a number of combinations were discussed, and their possibilities and limitations indicated. It was stated that manufacturers in this country were alive to the possibilities of this group of synthetics in this direction, and it is important to note that thermoplastic solutions having a vinyl acetate base are now produced in this country. Obviously, no adhesive can be of universal utility, but these new materials are inert, non-corrosive substances, they yield a film of a flexible rubbery nature, and they may therefore be considered for a variety of purposes in widely divergent fields.

Two samples of polyvinyl acetate adhesive solutions representing products manufactured in this country have been examined along similar lines to those recorded in the previous article and the results merit general consideration, both from the point of view of applications to which these materials are suited and on account of development work to produce modified media for some of those fields for which they are not quite so suitable. The test combinations used similar materials to those summarized in the previous article, viz.:—(1) Phenolic resin laminated paper board to paper. (2) Phenolic resin laminated to phenolic resin laminated. (3) Plywood to plywood. (4) Phenolic resin laminated board to plywood. (5) Phenolic resin laminated to brass sheet. (6) Brass sheet to plywood. (7) Soft rubber to plywood. (8) Bituminized cement asbestos board to similar board.

The lap joints in these various materials were made by brushing the solutions on to both mating surfaces and holding the joint together lightly under pressure for 3 hours. Joints were then allowed 3 days at ordinary temperatures to complete drying out before examination or subjection to test.

Table 1 summarizes the laboratory characteristics of the two adhesive solutions, and it will be noted that the acid values of them are very low. In this connection it will also be observed that no corrosion of the brass test pieces employed for the cementing tests occurred, as evidenced by the absence of greening.

Table 2 summarizes the efficiency of the junctions of various combinations of material. In this, tests on the two adhesive solutions are included on the test pieces without and with ageing, the former being kept at laboratory temperature for the same period as the eight specimens aged by hot and cold humidity test for 28 days. The hot and cold humidity test was the usual one in which the specimens were exposed in a cabinet controlled to give a day temperature of 55 to 60 degrees C. with a humidity of 65 to 75 per cent. and a night temperature of normal atmospheric of 18 to 22 degrees C. with 100 per cent. humidity and moisture condensing upon the specimens. Humidity was produced by trays of water in the bottom of the cabinet, temperature controlled by electrical heaters in the cabinet with external variable resistances, and uniformity of conditions achieved by means of a slow moving fan.

It will be noted that the two adhesive solutions did not behave with equal efficiency throughout the test series, and that the ageing caused some changes in some instances. In general, the solutions

Table 1.—Laboratory Characteristics of Air-drying Polyvinyl Acetate Adhesive Solutions.

Sample	No. 1	No. 2
Compositional:		
Volatile spirit (loss in weight, 3 hours at 110°C.), %	63.0	58.0
Total solids (thermoplastic resin base), %	37.0	42.0
	100.0	100.0
Acid value (expressed in terms of mgms. KOH per gm. of resinous base)	0.75	0.45

were satisfactory when one or both of the materials to be joined was of an absorbent nature. Thus, both solutions are quite satisfactory for securing paper to phenolic laminated, but unsatisfactory for giving a strong join between two pieces of phenolic laminated. One of them was excellent for securing plywood to itself, whereas the other one was unsatisfactory for this purpose, despite the absorbent nature of both pieces. A reasonable explanation for this can be found in Table 1 which shows material No. 1 to be of rather lower total solid content than material No. 2. This would correspond to a lower viscosity solution with better capacity for penetration and being absorbed by the wood. Another point of importance is the fact that phenolic laminated can be joined to plywood with reasonable results and that the warmth of the ageing test seemed to improve rather than deteriorate the juncture. This rather suggests that " bakelite "-faced plywood could use this adhesive with pressure and heat to fix the joint. It will be seen that neither material was satisfactory for brass to plywood or rubber to plywood, and while

Table 2.—Some Practical Test Results on Polyvinyl Acetate Adhesive Solutions.

Examination of Lap Joints on Various Materials Before and After Ageing for 28 Days under Hot and Cold Humidity Conditions.

Combination No.	Materials lapped	Air-drying polyvinyl acetate adhesive solutions			
		No. 1		No. 2	
		Laboratory temperature for 28 days	Hot and cold humidity for 28 days	Laboratory temperature for 28 days	Hot and cold humidity for 28 days
1	Phenolic laminated to paper	Very good. Materials could not be separated	Very good. No deterioration	Very good. Materials could not be separated	Very good. No deterioration
2	Phenolic laminated to phenolic laminated	Fairly good. Materials could be separated	Poor. Deteriorated. Materials could be separated easily	Poor. Materials could be separated easily	Poor. Materials could be separated easily
3	Plywood to plywood	Excellent. Materials could not be separated; laminal break	Excellent. No measurable deterioration	Poor. Materials could be separated easily	Poor. Materials could be separated easily
4	Phenolic laminated to plywood	Good. Materials could only be separated with extreme difficulty	Good. No deterioration	Poor. Materials could be separated easily	Good. Improved. Materials could only be separated with difficulty
5	Phenolic laminated to brass	Poor. Materials could be separated easily	Poor	Poor	Poor
6	Brass to plywood	Poor. Materials could be separated easily	Poor	Poor	Poor
7	Soft rubber to plywood	Poor. Materials could be separated easily	Poor	Poor	Poor
8	Bituminized cement asbestos board to bituminized cement asbestos board	Poor. Materials could be separated easily	Fairly good. Materials could be separated, but join quite tenacious	Poor. Materials could be separated easily	Fairly good. Materials could be separated, but join was tenacious

unsatisfactory for bituminized cement asbestos board, it will be seen that efficiency of both solutions improved during the ageing process. This again suggests that satisfactory bonding could be readily achieved with heat and pressure.

The joints in all cases were of a rubbery nature as distinct from the hard rock-like nature of baked synthetic resin joints.

It was thought that exposure to low temperatures might cause crystallization and weakening of the join. Consequently, some of the combinations prepared as described above were submitted to a temperature of approximately – 50 degrees C.

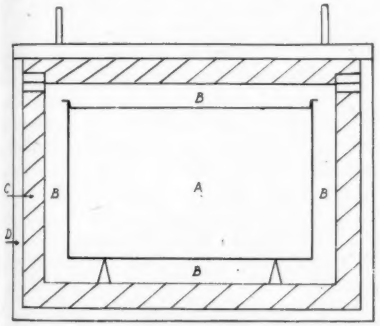


Fig. 1.—Chest for low-temperature tests using solid carbon dioxide. A, Brass box with brass lid for specimens; B, Interspace for carbon dioxide; C, Insulation; D, Wooden outer structure.

for a period. For this purpose they were placed in a dricold cabinet for 24 hours, during which it required approximately one hour for the temperature to fall to – 50 degrees C., and for the remainder of the 24 hours the temperature was held between – 40 and – 50 degrees C. The nature of the test cabinet is shown diagrammatically in Fig. 1. It will be seen that the outer cabinet consists of a double walled box, the outer lining of wood, the inner one of brass, with a thermal lagging of cellulose powder between them. The actual test box is of brass, and it can be packed around entirely with solid carbon dioxide. The main cover is of lagged construction of similar design to the box itself. Temperatures could be read by means of properly insulated thermocouples, contacting with the work, brought out through suitable holes. The results of the test were rather peculiar. With paper secured to bakelite laminated little or no deterioration occurred and the junctions satisfactorily withstood the test. The same applies to solution No. 1 for plywood cemented to itself, but with this combination solution No. 2 showed some slight improvement, due apparently to the cold exposure. In the case of bakelite laminated attached to plywood, the result was poor, deterioration being noted in the base of solution No. 1 and the poor quality being unchanged in the case of solution No. 2. Detailed results are summarized in Table 3.

There would appear to be a good field for this type of adhesive solution for securing papers to materials having a polished or glazed surface, such as bakelite laminated and metals in general, and with proper consideration of grade, and perhaps a little development work, for securing absorbent materials to absorbent materials, such as wood to wood, fabric or paper to wood, etc. Other applications that justify exploration are those that involve metal assemblies that require sealing against the ingress of air or moisture. For example, metal seatings, interstices between screws and tapped holes, spun-over junctions, etc., etc. In this connection the adhesive qualities of the two polyvinyl acetate solutions were compared with those of other established sealing paints or solutions when applied to nickel-plated brass. The latter presents a smooth, shiny surface with no characteristics in itself for adhesion.

These adhesion test results are summarized in Table 4. The adhesives were applied to the nickelled brass specimens by brush and allowed to air dry. The " surface " drying times were noted because these are important in those engineering assembly operations that are carried out on a continuous line, giving a measure of the time lag involved before passing on to subsequent operations. It will be noted that the polyvinyl thermo-

Table 3.—Some Practical Test Results on Polyvinyl Acetate Adhesive Solutions.

Examination of lap joints in various materials after exposure to a temperature of minus 50°C. for 24 hours.

Combination No.	Materials lapped	Quality of joint after exposure to − 50°C.	
		No. 1	No. 2
1	Phenolic laminated to paper	Good. Materials could be separated only with extreme difficulty. Very slight deterioration	Very good. Materials could not be separated. No deterioration
3	Plywood to plywood	Very good. Materials could not be separated, but evidence of very slight deterioration	Fairly good. Materials could be separated. Some improvement
4	Phenolic laminated to plywood	Poor. Materials could be separated easily. Deterioration	Poor. Materials could be separated easily. No change

plastic solutions are satisfactory in this direction. However, before subjection to the hot and cold humidity tests, the specimens were allowed to air-dry for 3 days in order to allow them to fully dry-out. Adhesive qualities were tested by bend and by scratch tests, initially and after 7 and 28 days exposure to the test conditions. From the tabulated results it will be seen that the chlorinated rubber base sealing paint started very well but rapidly deteriorated. A pigmented glyptal resin base adhesive opened the test in excellent condition and underwent only very slight deterioration. Similarly a china wood oil modified glyptal product only showed slight deterioration. On the other hand, neither of the polyvinyl acetate solutions started quite so well because they could with difficulty be removed as a rubbery film, more by peeling than by real absence of adhesion. Yet they withstood the test unchanged. It is considered that they merit serious consideration for many classes of metal-to-metal seal, not only for moisture proofing, but also for the retention of air tightness.

The laboratory characteristics of the three " varnish " type adhesive sealing solutions used in these tests are given in Table 5 in order that they may be compared with the polyvinyl solution.

Table 4.—Adhesive Qualities of Various Sealing Solutions Applied to Nickel-plated Brass

Behaviour During 28 Days Hot and Cold Humidity Exposure

Period of test in days	No. 1 chlorinated rubber base	No. 2 Glyptal resin base	No. 3 Oil modified glyptal base	Polyvinyl adhesive solution No. 1	Polyvinyl adhesive solution No. 2
0 (Initial)	Very good. No cracking on bending and could only be scratched off with thumb-nail with difficulty	Excellent. No cracking when bent and could not be scratched off with thumb-nail	Excellent. No cracking when bent and could not be scratched off with thumb-nail	Very good. No cracking when bent, could only be scratched off with difficulty, and then tended to be peeled like a rubbery film	Very good. No cracking when bent, could only be scratched off with difficulty, but then tended to be peeled like a rubbery film
7	Rather poor, lifting on bending and could be scratched off fairly easily	Very slight cracking on bending but otherwise no deterioration	Slight deterioration. Slight cracking of film on bending and could be scratched off with difficulty	Ditto	Ditto
28	Poor. Lifted badly on bending and could easily be scraped off	No further deterioration. Very good	No further deterioration. Good	Ditto, no deterioration	Ditto, no deterioration
Surface drying times of the test films	5 mins.	5 mins.	6 hours	5 mins.	5 mins.

Table 5.—Laboratory Characteristics of Red Oxide Pigmented Adhesive Sealing Solutions.

Type	No. 1 Chlorinated rubber base	No. 2 Glyptal resin base	No. 3 Oil modified glyptal base
Compositional :			
Volatile spirit (loss in weight, 3 hours at 110°C.), %	59.0	63.5	32.0
Total solids, %	41.0	36.5	68.0
	100.0	100.0	100.0
Physical :			
Viscosity at 25°C., centipoises	1,250	850	550
Specific gravity at 25°C.	1.052	0.970	1.390
Drying time, minutes :—			
Surface	15	5	60
Hard	180	60	960

It is pointed out that the polyvinyl adhesive solutions are homogeneous solutions, practically colourless, giving a colourless film. They are therefore far more convenient and easy to apply than the pigmented varnish adhesives. They dry rapidly and any sticky contamination over other surfaces, benches, operators' hands, etc., can readily be cleaned with solvent such as ethyl acetate. Brushes and containers can similarly be cleaned, but the most convenient mode of application is through an appropriately shaped nozzle from a cylinder or container to which low air pressure is applied. The work can be suitably jigged and rotated beneath the nozzle. In these respects, the polyvinyl adhesives resemble the nitro cellulose base cements that are so popular for their ease of application, but which are prone to fail due to ageing.

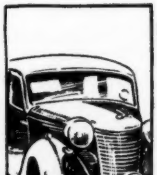
An interesting American application of the polyvinyl acetate thermoplastic solutions should be noted. In the food canning industry, where tin plate containers of the type popularly known as " open top sanitary cans " are employed, the top and bottom ends of these cans are discs with a formed periphery over which a layer of plastic compound is applied. The ends are then fitted by a simple double curling operation, and the dope relied upon to give a hermetic seal. One such dope employed is a solution of polyvinyl acetate resin (15 per cent.) in a mixture of benzene (45 per cent.) and toluene (40 per cent.), the percentages being by weight. Another use in this field for this class of solution concerns canned beer. Here, a varnish consisting of the copolymer of vinyl acetate and chloride is used to line the " tin."

Naturally, users proceed warily with new products, and they must conduct tests and extended trials. The foregoing is intended more as a broad unbiased review of the possibilities of these relatively newcomers to the already wide range of adhesives. Possible applications have to some extent been indicated, and it would be futile to endeavour to make specific recommendations. Nevertheless, these notes can be concluded reiterating a few combinations, viz., sticking papers, fabrics and treated fabrics to any material; bonding bakelite-metal and other thin veneers to wood; the plies themselves in plywood; metal-to-metal junctions for sealing; fixing cork or other liners to bottle caps; sealing glass windows or plastic glasses into frames, etc., etc. Adhesives are not necessarily confined to the two products tested and discussed herein; they only represent a type from which numerous combinations varying with respect to hardness, adhesive character, drying time and other physical or mechanical properties, or with respect to fillers that may be incorporated, can be evolved, going far to meet the requirements both of fabrication or process and of serviceability. It is to be understood that neither of the thermosetting adhesive solutions was specifically designed for the jointing of the range of combinations used in the tests and that they were examined in this manner solely to obtain broad information upon their possibilities.

World's Industry Employs Plastics

ELECTRICAL

Cable covers in benzyl cellulose are apparently being used with great success by Russian cable manufacturers. A mixture of 100 parts benzyl cellulose with 70-71.6 per cent. carbon black, 36 parts tricresyl phosphates, 22 parts kaolin and 3 parts red ochre has proved satisfactory. The Ostwald number for toughness of a 3 per cent. solution of benzol and alcohol is 6-7. The water resistance of the compound has been determined gravimetrically by measuring its insulating powers with respect to temperature and time. Moisture has little effect upon mechanical properties. Resistance to acids and alkalis and to liquid fuels and oil is good. The cable coverings were also subjected to ageing tests of 3.5 to 5 months at 16 degrees C. and at 50 degrees C. with exposure to atmospheric air, with or without ultra violet light. Flexibility of the materials tends to decrease on ageing in air. The disadvantage of benzyl cellulose mixes of this type are their brittleness at low temperature and their tendency to soften and lose strength at elevated temperatures. Substitution of the tricresyl phosphate by linoxyl, glyptals, natural rubber and chloro-naphthalenes tended to raise the temperature at which excessive softening occurred. Fuller details are contained in the published transactions of the Scientific Research Inst. Plastics (Russia), Peoples Commissariat of Heavy Industry, 1939/3/69. **Moulded circuit breaker** by Heinemann Circuit Breaker Co., specially designed for aircraft control panels, is in Bakelite and is specially designed for rear-fixing, the switch handle projecting through the panel. The circuit breaker casing is divided longitudinally, fixing bolts being inserted after moulding. **Fairlead guide blocks** in graphitized phenolic resin moulded by General Industries Co. and Richardson Co. have solved many difficulties formerly encountered in the production and assembly of these units into the completed aircraft. Design is such that provision is made for automatic self-alignment, whilst an eccentric centre boss in the guide block provides for easy centring. To facilitate assembly, the plastic guide, which is split and consists altogether of four parts, is mounted on an aluminium base-plate with a special rapid-action nut and bolt. **Electro static voltmeter** built by Multi-Products Tool Co. has vanes of the electro static unit moulded in bakelite. High electrical resistance and dimensional stability were required of this unit. Base of power valves requiring high dielectric fatigue strength and great resistance to breakdown, together with low power factor losses, are moulded in Durez resin by Norton Laboratories.



MOTORS

Retreading of natural rubber tyres with thiokol is said to have become possible as a result of recent developments by the Dow Chemical Co. The Ford Motor Co. has asked War Production Board for permission to retread tyres on the cars owned by the company's 110,000 workers with thiokol. It is intended to use 2 lb. of thiokol per tyre, this giving a tread 1/10 in. thick, and said to be good for 3,000-5,000 miles of

moderate driving at speeds below 40 m.p.h. Retreading would be done in Ford's tyre factory, and the tyres would be inspected regularly for defects. **Tubeless tyre for heavy vehicles** is announced by Goodrich. Air is retained by means of a special design, effecting a saving of some 7 per cent. in total rubber used on the tyre assembly. **Greatly increased production** is envisaged by the Standard Oil Co. (New Jersey) as a result of improvements effected in its butyl rubber plant. The company is also manufacturing a new synthetic rubber, known as Flexon, whilst a process has been developed for manufacturing butadine direct from butane. **Differential wheel assembly** provided with laminated phenolic resin inter-wheel bushings is produced by Differential Wheel Corporation. The material employed is referred to as "Synthane." It is used in the form of plate stock machined to form and is said to be graphite impregnated.

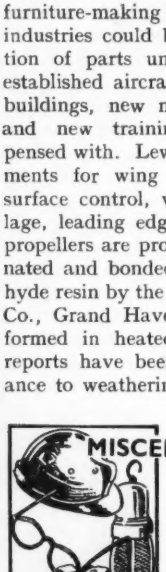
GENERAL ENGINEERING

Permissible loads for polyvinyl chloride are considered by Bachmann in "Z.V.D.I." 1940/84/425. The author establishes the relationship between continuous strain and temperature increase (which occur with the material under load) and local molecular changes. In this respect, polyvinyl chloride is said to be similar to the organic glasses of lower molecular weight. Fatigue strength and impact strength of polyvinyl chloride in its various forms are also dealt with as functions of temperature and of time. **The effect of resin additions** on the properties of moulding sands has been investigated by Pragoff and Albus, reporting in the transactions of the American Foundrymen's Association. The resin increases the dry strength of the moulding sand, and, furthermore, confers other valuable properties. **Pressure gauges provided with acrylic resin dial covers** integral with retaining ring and bezel are being produced by Ashcroft Gauge Division of Manning, Maxwell and Moore. Considerable experimental work was required to produce a successful moulding, but this has now been done.

AIRCRAFT

Drill jig production for aircraft work is said to be facilitated by an interesting process, details of which have just been made public. Drill bushings are attached to a master part, which in turn is placed in a mould, thus finally providing a mould for a suitable plastic base. After the moulding material has hardened, bolts holding the bushings in position may be removed, and the jig is then finished and ready for use. The system is described in "Automotive and Aviation Industries," 1942/87 (No. 1) 36, in relationship to practice by Lockheed and Vega. Difficulties consequent upon shortage of iron and steel are, to some extent, overcome in this way, whilst wooden jigs with inserted metal bushings are replaced by a more reliable product. Lockheed adopted a special compounded thermoplastic, said to have a casting temperature of 225-235 degrees F., with a minimum softening point of 200 degrees F. Vega employed a phenol-formaldehyde composition containing 25-30 per cent. ground walnut sheel flour filler. Woodflour and scrap plastic have also been satisfactorily used as fillers in this connection. By adding an acid catalyst to the resin the work is set up and ready for use in 2-8 hours, depending on size. Plastic jigs wear even less than those in light alloys. **Replacement of metal by plastic-bonded woods** is also considered in the issue of "Automotive and Aviation Industries" previously referred to. The elimination of metal, it is concluded, will go far to overcome certain limitations associated with current aircraft designs,

namely, shortage of strategic materials, shortage of metal, inadequate machinery and plant capacity, and shortage of skilled metalworkers. Lewis, of the Timms Aircraft Corporation, considers that plastic-bonded wood as a basic structural material would enable 'plane production to be nearly doubled, for the furniture-making and allied woodworking industries could be used for the fabrication of parts under the supervision of established aircraft manufacturers. New buildings, new metalworking machinery and new training could all be dispensed with. Lewis describes the requirements for wing construction, flap and surface control, vertical stabilizers, fuselage, leading edges and fairings. Wood propellers are produced in maple impregnated and bonded with phenol-formaldehyde resin by the Camfield Manufacturing Co., Grand Haven. The propellers are formed in heated steel dies, and good reports have been given on their resistance to weathering.



MISCELLANEOUS

Injection moulding of the Igamides (i.e., current German terminology for Nylon) is discussed by Beck-Schapp in "Kunststoffe," July, 1942, page 205. Considerable difficulties have apparently been caused by the high fluidity of the heated mass, and numerous types of injection nozzle have been constructed, although, it appears, none has yet proved entirely satisfactory for complete automatic operation. Best results have so far been obtained by a specially designed valve, the closing of which takes place on the exit side, and in which provision is made for heating in order to prevent premature solidification. Closing of injection nozzle is effected by a specially designed spring device. **The Isoma injection moulding machine,** described by Gastrow, on page 211 of "Kunststoffe," July, 1942, is also equipped with another special type of nozzle which has proved successful in handling this particular group of plastics. **Resistance of polished surfaces to wearing and weathering** where these actions include abrasion is discussed in "Modern Plastics" (September, 1942, page 79). The instrument used is similar to that devised by Chalmers for measuring surface hardness of electro deposited metals (see Journal Inst. Met., 1941/67/295). It consists of a device for allowing standardized abrasive particles to fall over a known time under fixed conditions on the surface to be tested, abrasion being measured by alteration in the light reflective powers of the surface being tested. **Detection and analysis of polyvinyl acetal** is described by Gibello in "Rev. Gén. Caoutchouc" (1941/18/198; 223). The polyvinyl acetal is distilled with hot 20-per-cent. sulphuric acid, when it breaks down to give polyvinyl alcohol and aldehyde. In acid solution the former gives a blue coloration with iodine. Not all acetals, however, are equally amenable to this method of analysis, which may not yield quantitative results. A new French process proceeds as follows:—One gm. of the sample is heated in an Erlenmeyer flask on a water bath with 40 gm. benzyl alcohol and 25 c.c.s semi-normal alcoholic potash. The mixture is refluxed for two hours. The contents of the flask are then cooled to room temperature, after which 10 gm. methylated spirits are added, followed by the gradual addition of 75 gm. of distilled water with constant shaking: 25 gm. saturated aqueous sodium chloride are then added. Three drops of phenolphthalein are next added and the solution titrated with semi-normal sulphuric acid. With the disappearance of the red colour in the aqueous layer an excess of 0.5 c.c. sulphuric is run in and back titrated with semi-normal sodium hydroxide. This gives free polyvinyl acetal. Free polyvinyl alcohol is estimated by exhaustive treatment of the resin sample with acetic anhydride in pyridine. The total vinyl acetal is estimated as described, free alcohol being determined by difference.

Mechanical Properties of Plastics at Low Temperatures

Summarizing Recent Investigations on the Low-temperature Properties of Plastics with respect to Elastic Modulus and Deformation Characteristics

THE extended use of plastics in aircraft and military equipment generally has rendered it imperative that the properties of these materials at low temperature be investigated. It is well known that, at low temperatures, certain types of iron and steel and many non-ferrous metals become brittle. This, fortunately, is not the case with many plastics, nor with the majority of light metals.

Röhrs, of Charlottenburg, and Hauck have recently published a detailed account[1] of their investigations on the effect of temperature on the mechanical properties of thermo-hardening and thermo-plastic materials between the range −70 degrees C. and +20 degrees C. The properties investigated included modulus of elasticity, yield point, and relationship between plastic deformation and total deformation.

The materials investigated are summarized in Table 1. They include, with the exception of those under headings D and B, commercial materials on the production of which no data could be obtained. Materials in group D were prepared in the laboratory.

Samples for groups A to C were of cylindrical form of diameters between 15 and 20 mm., and a length of 55 mm. For group D, the diameters were the same, the length, however, being 40 mm. Shorter specimens were used for yield point test pieces, the length in this case being equal to diameter.

Modulus of elasticity and yield point

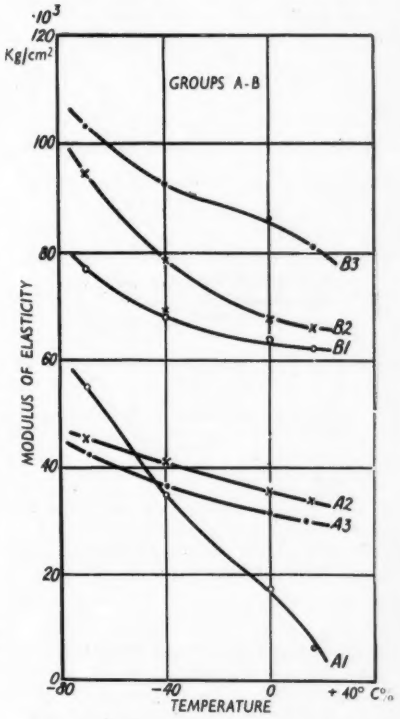


Fig. 1.—Elastic moduli of various thermo-setting resins in relationship to temperature. Note, in particular, the anomalous behaviour of sample A1 (cast resin without filler).

were measured on a six-ton universal machine (Mohr and Federhaff). Loads were determined by means of a pendulum dynamometer and deformation by means of a Marten's mirror extensometer. The polystyrenes (group D) were investigated on a five-ton universal testing machine, deformation being measured by a dial gauge reading to 0.01 mm.

Loads were applied at a speed of

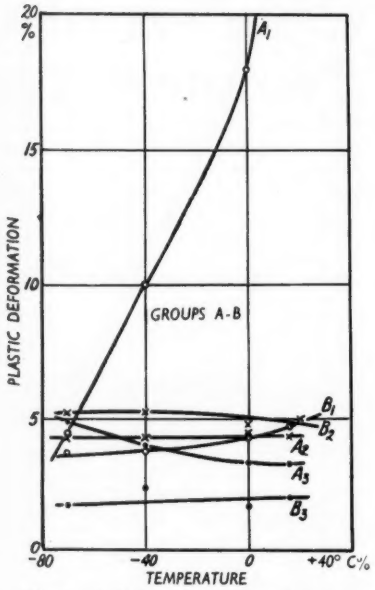


Fig. 2.—Relationship with respect to temperature of the ratio between plastic and total deformation for various thermo-hardening resins. It will be observed that sample A1 (see Fig. 1) again yields anomalous results.

300 kg./min. for the measurement of elastic moduli and at 500 kg./min. for measurement of yield point. Tests were carried out at +16 degrees C., +18 degrees C., 0 degrees C., −40 degrees C. and −70 degrees C. For material groups A to C, two determinations were made on each specimen, whilst for group D one measurement only was made.

In determining the modulus of elasticity a preload of 50 kg. was applied, followed by a load of 100 kg. at the speed already given. Deformation was then determined, after which the load was removed, leaving only the preload, residual plastic deformation being then determined. Further loading was then applied up to 200 kg., total and plastic deformation being read as before.[2] The process was repeated for a load of 300 kg. and so on up to maximum loading of 1,200 kg. or a permanent extension of 1.5 per cent. Modulus of elasticity and the ratio of plastic to total deformation were found from the stress-strain diagrams obtained.

In order to determine yield point, the load was increased to 6,000 kg., stress and strain being automatically recorded.

Fig. 1 shows the modulus of elasticity of thermo-hardening plastics in relationship to temperature. With the exception of material A1, the curves are all similar, the modulus of elasticity increasing with decreasing temperature. Curves for yield point are more affected by temperature, the order of material in groups A and B being opposite to that shown in Fig. 1.

Ratio between plastic and total deformation is given in Fig. 2. Only in the case of material A1 is the ratio strongly affected by temperature. As this particular material is a cast resin containing no fillers and possessing properties different from those of other plastics, further tests were made. These involved the determining of modulus elasticity, yield point and deformation ratio in relationship to curing time at a temperature of 100 degrees C.

Results were somewhat inconclusive. Apparently the coefficient of thermal expansivity provides a good indication of

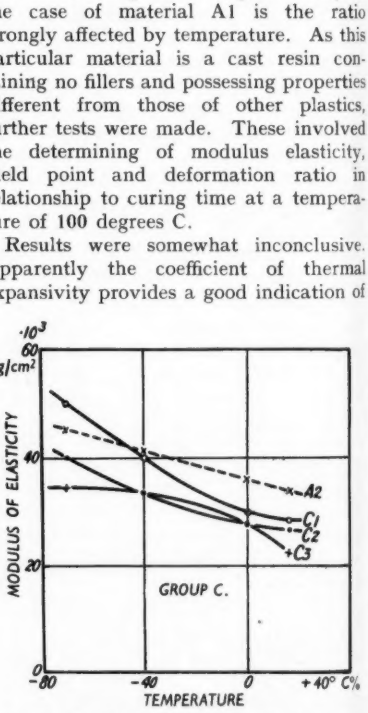


Fig. 3.—Elastic moduli of certain thermoplastics in relationship to temperature. The broken line representing the behaviour of a cast phenolic resin is inserted for purposes of comparison.

the degree of curing of thermo-hardening resins in the cast form. Further investigation, however, is required along these lines in order to confirm fully the results obtained.

Figs. 3 and 4 show the relationship between elastic moduli and yield points in the case of thermo-softening plastics (group C). The broken lines in these figures are those for material A2, which is inserted for purposes of comparison. Although it is clear that the influence of temperature on the mechanical properties of these plastics is greater than in the case of thermo-hardening resins, definite conclusions cannot be drawn as the production history of the materials was unknown.

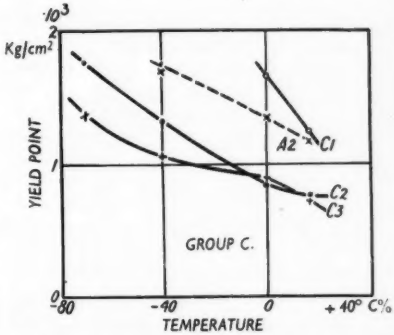


Fig. 4.—"Yield point" of certain thermoplastic resins in relationship to temperature. Broken line representing behaviour of cast phenolic resin is inserted for purposes of comparison.

Behaviour of Polystyrenes

Partly to elucidate this point, the authors manufactured 10 types of polystyrene plastic (group D) in the laboratory. Styrene was polymerized at 80 degrees C. and 100 degrees C., using as catalyst benzoyl peroxide in amounts of 0, 0.1, 0.2, 0.5 and 1.0 per cent.

The samples obtained were subjected to the tests previously described. Modulus of elasticity and yield point were found to increase with decreasing temperature. The authors observed that the values of these two qualities were smaller in the case of polystyrenes produced with smaller quantities of catalyst; these results do not agree with earlier American findings.[3]

The authors finally conclude that no definite arguments as to the chemical structure of polymers of this type can be based on consideration of a limited number of mechanical properties.

It is somewhat to be regretted that the work recorded here was not of a more detailed nature. Although, for structural purposes, deformation characteristics and elastic moduli are factors of the highest importance, they have little meaning unless considered in conjunction with other mechanical properties, more

Table 1.—Plastics Investigated by Röhrs and Hauck.

Designation	Substance	Trade name	Filler
A_1	Phenol-formaldehyde resin	Dekorit Cast-Resin 300a	—
A_2	Phenol-formaldehyde resin	Dekorit Cast-Resin 102	With pigments
A_3	Phenol-formaldehyde resin	Dekorit Cast-Resin F	With pigments
B_1	Phenol-formaldehyde resin	Neoresit-Moulding Material Type S	Wood flour
B_2	Phenol-formaldehyde resin	Neoresit-Moulding Material Type Z_1	Cellulose fibre
B_3	Urea-formaldehyde resin	Neoresit-Moulding Material Type K	Cellulose flakes
C_1	Polymethyl-methacrylate	Plexiglas M 222	—
C_2	Polyvinyl chloride	Igelit PCU 570	—
C_3	Polyvinyl chloride	Igelit PCU 23	—
D_1 to D_{10}	Styrene polymerized at 80 deg. C. and 100 deg. C.	—	—

particularly impact strength. The moment is probably opportune also for a more complete investigation into the fatigue properties of plastics, especially under conditions of preloading and over a wide range of stress frequencies, such as may arise, for example, in modern high-speed, high-altitude aircraft, although data so gained would obviously be of great general value.

[1] Röhrs and Hauck "Kunst. Techn., 1940/11/213. Also "Kunstoffe," 1942/32/141.
[2] Hauck, "Kunstoffe," 1941/31/119.
[3] Curme and Douglas, "Indust. Eng. Chem.," 1936/28/1123.

Standardization of Plastics in Germany*

Presenting a Brief Note on Current Standard Specifications for Plastics Employed in the Electrical Industries

FOR about 19 years now plastics have been standardized in Germany for electrical purposes. This fact may not be well known, as these materials were classed under the heading of non-ceramic and rubber-free insulators. The standards were revised from year to year, and the numbers listed were increased from about nine to not less than 26 different plastic materials, including four types produced by cold pressing.

After the previous revision in 1937 the lists were recently again reviewed. Latest data are summarized in the accompanying table.

Compared with the older tables, the following additions will be noted:—The impact strength of several types has been added, and certain values in this regard modified; thus the impact strength of material O (phenolic-resin with wood-flour filler) is reduced from 2.0 to 1.5 cm.kg/cm². For testing surface resistance the moulding skin is no longer removed, and the actual value has, in some cases, been reduced; on the other hand, it has been increased for certain special materials. Some physical values of material 8 (natural or processed bitumen with inorganic filler) have been increased, owing to the better properties obtained.

Material types X and Y, consisting of lead-borate with mica and cement or waterglass, are listed in the table owing to the fact that they are produced by manufacturers of plastic parts for the electrical industries and are widely employed in many directions.

Moulding material types are subdivided according to their composition and treatment, and some mechanical, thermal and electrical properties are given. The majority of types are non-laminated, only T3 and Z3 coming into this category.

Data summarized in the Tables were compiled from results obtained on standard test pieces, for the production of which, again, standard specifications have been issued. Samples took the form of bars 10 mm. by 15 mm. by 120 mm., or plates 3-4 mm. thick with an edge length of at least 120 mm. Only for type X material is no standard testing method laid down, as in this particular instance resistance to destruction by arcing is the only property, other than those of a mechanical nature, called for.

* "Elektrotechnische Zeitschrift," 1942/63/268.

Table of Moulding Material Types, 1942 Revision.

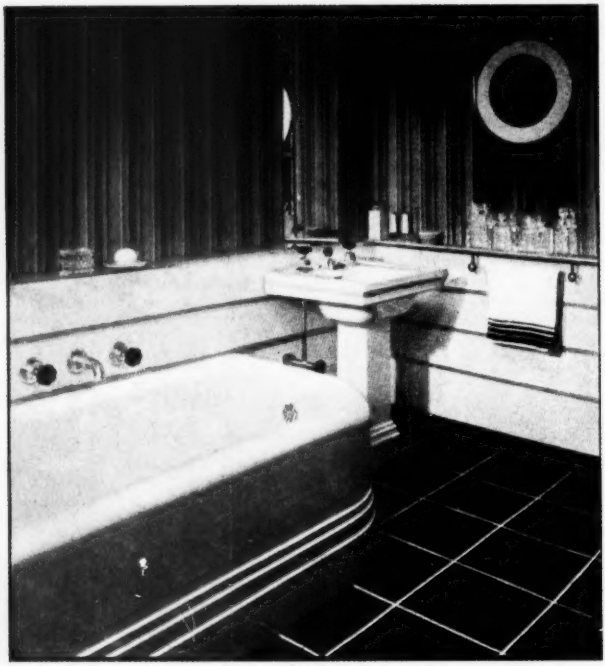
	Mechanical properties			Electrical properties			Produc-tion
	Bending strength	Impact	...	Surface	Spec.	Dielectric	

Table of Moulding Material Types, 1942 Revision.

Type	Composition	Mechanical properties: Bending strength min. Kg. sq. cm.	Bending strength min. Lb./sq. in.	Impact bending strength min. Cm. kg./sq. cm.	Impact strength min. Cm. kg./sq. cm.	Electrical properties: Surface resistance factor	Spec. Resistance Ωcm.	Dielectric loss factor tan δ maximum	Production process
11	Phenolic resin with inorganic filler	500	7,110	3.5	1.0	8	—	—	Hot moulding
11						10	10^{11}	0.1	
12		500	7,110	3.5	2.0	8	—	—	
M		700	9,954	15.0	15.0	7	—	—	
O	Phenolic resin with wood flour filler	600	8,532	5.0	1.5	8	—	—	
O						10	10^{11}	0.1	
S		700	9,954	6.0	1.5	8	—	—	
S						10	10^{11}	0.1	
T1	Phenolic resin with textile fibre filler	600	8,532	6.0	6.0	7	—	—	
T2		600	8,532	12.0	12.0				
T3		800	11,350	25.0	18.0				
Z1	Phenolic resin with cellulose filler	600	8,532	5.0	3.5	7	—	—	
Z2		800	11,350	8.0	5.5				
Z3		1,200	17,064	15.0	10.0				
K	Urea resin with organic filler	600	8,532	5.0	1.2	10	—	—	
K						10	10^{11}	0.1	
6	Natural resin, natural or processed bitumen with inorganic filler	350	4,982	3.5	3.5	8	—	—	
7		250	3,560	1.5	1.5				
8	Natural or artificial bitumen with inorganic filler	180	2,560	1.2	1.2	10	—	—	
A	Acetylcellulose with or without filler	300	4,266	15.0	10.0	8	—	—	
A						10	10^{11}	0.1	
2	Synthetic resin with asbestos and another inorganic filler	350	4,982	2.0	1.5	8	—	—	Cold moulding
3	Synthetic resin with asbestos and another inorganic filler	200	2,844	1.7	1.2	7	—	—	
4	Natural or processed bitumen with asbestos and another inorganic filler	150	2,130	1.2	1.0	7	—	—	
Y	Lead borate with mica	1,000	14,220	5.0	5.0	10	—	—	Hot moulding
X	Cement or waterglass with asbestos and another inorganic filler	150	2,130	1.5	1.5	—	—	—	Cold moulding

As compared with earlier specifications, certain requirements called for with respect to mechanical and electrical properties have been modified in this summary representing the most recent German standards for plastics for the electrical industry. Types Y and X, consisting of lead borate or cement bases with various fillers, are inserted by reason of the fact that they are widely employed by manufacturers of electrical components, who, at the same time, also manufacture synthetic resin parts.

PLASTICS IN ASSEMBLED



By
G. FEJÉR

Fig. 1.—Example of unit bathroom. (With acknowledgments to "Studio.")

II.—SMALL BATHROOMS

IN the previous issue we have dealt with the aspects of plastics for the manufacture of assembled kitchen units, and as some of the details described apply for bathrooms as well, the writer has omitted many references in order to avoid unnecessary repetitions. In the case of bathrooms, there are numerous examples of pre-assembled or prefabricated components, and we shall comment on these below. Our Fig. 1 and Fig. 2 illustrate prefabricated bathrooms manufactured in the U.S. over six years ago, although these are not the earliest representative examples of workshop-made bathrooms. As far back as in 1932 the manufacture and nation-wide distribution of entirely factory-made bathrooms was visualized and brought to a commercial stage in that country. Now that hardly a week passes without some further sensational news on prefabrication, and that the U.S. Government has placed orders for "Defense Housing" with scores of prefabricators, one would be inclined to think that the whole principle of workshop-manufacture of buildings is just a recent and temporary development. It is true that there are tens of thousands of prefabricated "demountable" buildings which are meant to be used for the duration only, but the real justification for workshop

ED BUILDING STRUCTURES

assembly is the ever-present tendency to try to improve quality without additional costs.

As the needs and functions of bathrooms had been brought to a more or less standard level throughout the U.S. it was a quite obvious step to attempt to manufacture the bathroom walls and floors as well as the fittings, so that the whole room could be delivered as a working unit. Some of the workshop-made wall panels and floors have shown themselves superior to the site-finished ones in the same way that factory enamelled bathtubs are superior to those painted by the local handyman.

International Standards?

To some extent the design of a small bathroom is dictated primarily by the justified human needs on the one hand and by the average human measurements on the other. This being so, bathrooms may be made completely assembled and shipped to the opposite parts of the world, and the main measurements and design would equally apply whether the bathroom is used in a liner, bungalow, flat or family house, without regard to geographic or other local conditions. This theory could be supported by innumerable comparative examples of higher rented flats, apartments and modern houses, as we find little difference between bathrooms as far apart as Eastern Europe, South Africa, England and the United States. If, however, we compare municipal housing schemes which have been built for the population of the lower income groups, the design and finish of bathrooms (if any) are so different in every country that one begins to doubt that a range of international standards can be developed at all. In typical examples of English workers' flats and houses[1] built in London, Birmingham, Liverpool, Leeds, etc., full-length baths and lavatory basin are provided in bathrooms, which have, as a rule, direct access to daylight

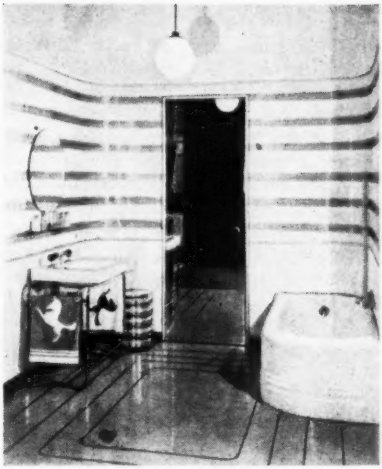


Fig. 2.—Another example of the unit bathroom.

and natural ventilation. The w.c. is as often in the bathroom as built separately. Flats and houses built on the Continent for people of the same " income group " as in Gt. Britain generally have far less comfortable bathrooms, if any. In modern French housing schemes in and around Paris central heating is generally adopted, and some of the blocks of workers' flats have imposing dimensions, appearance and finish comparable with luxury flats. The bathrooms, however, are very different from the average English counterparts. In the housing scheme Cité de la Muette (a combination of three-storey blocks and 163-ft. skyscraper towers) only less than half of the flats have bathrooms (three-quarter or " minimum " bathtubs). There are more shower-rooms instead, and these are generally fitted with indirect lighting and ventilation. In the Boulogne-Sur-Seine scheme only the more expensive types have bathrooms, and showers are generally provided in washrooms. The maisons Alfort and Champs

des Oiseaux schemes have similar facilities and the separate w.c.s are generally ventilated into washrooms or drying spaces. In the corresponding examples tabulated by the Building Centre Committee we find that schemes built in Rotterdam and Amsterdam have no higher standards. Four out of five examples have no bathroom at all, and in most of the types there are not even showers. Municipal housing schemes as far apart as Denmark and Spain show certain similarity in services, substituting showers for baths.

In view of these facts, it is difficult to decide what will emerge finally as international standard equipment for bathrooms. Quite apart from economic considerations, there is something to be said for the showers, as some authorities maintain, on hygienic grounds, that showers are much more healthy than baths. The main reasons, however, which have lead to the extensive use of showers instead of baths are, of course, the economic considerations, but it can be hardly expected that these (especially if tucked away in a dark w.c. or scullery) could be adequate as substitutes for bathrooms such as are built by the L.C.C.

By examining the conditions under which the shower has been chosen instead of bath, we find that it is not always for reasons of space. In the French examples, for instance, shower rooms and w.c. together would easily suffice for small bathrooms. It is sometimes the cost of the fitments and sometimes the fixing labour which necessitates some simplification. Economy of heat and water is another point in favour of the showers. (Incidentally, 5 ins. of bath water gives sufficient volume for a good shower.)

All this rather seems to point the way for further developments in unifying standards, and we have every indication that, with prefabrication and workshop assembly, the cost of fitments and fixing labour can be reduced, and thus bathrooms may be made available in places where it has not been found possible or convenient to provide them so far. The importance of showers (situated over the bath tub) as auxiliaries has been long recognized, although their absence in many English homes is rather remarkable.

After the war prefabricators will certainly provide a number of standard types of bathrooms, of which those between 35 and 40 sq. ft. area appear to be the most promising in their international applicability. Let us assume that such bathrooms will be produced for new town dwellings as well as for alteration and modernization. In such cases hot and cold water, electricity and canalization will be available as a matter of course, and other services, such as central (or district) heating, air conditioning and communal laundry facilities may also be provided.

At all events, the bare essentials of a bathroom are:—Bath tub and shower, lavatory basin, w.c., cupboard. There would also be other items as optional fitments; for instance, ironing board and clothes dryer (or airer), heaters and towel rails, hooks, additional shelves, etc.

Such bathrooms are, of course, not suitable for laundering, except small objects, and not meant to be used as boiling rooms, nor is it possible to incorporate in a space of, say, 35 sq. ft. any luxurious dressing tables. But this is approximately the type that emerges as a sort of average between American, English and various Continental standards. The statistical facts showing that approximately two thirds of the population of Britain are living in towns containing over 20,000 inhabitants, and that the majority are living in households not exceeding two or three persons, are further indications that there will be an increased demand for the smaller up-to-date dwelling. This means that we shall have to build more bathrooms per person than ever before.

It would lead us too far from the subject to tabulate possibilities of measurements and arrangements of such small bathrooms in more detail. Let us, however, consider the assembly questions which are involved in the prefabrication of bathrooms.

The Principles of Assembly

There are literally hundreds of methods which have been tried out in this connection, and which have direct or indirect significance in the formation of bathrooms as an integral part of the building structures. The writer has grouped some of the most interesting examples under three headings—according to their manner of assembly. It is the extent and the manner of assembly which are the only new features of prefabrication, and which are of the utmost importance from the industrial point of view. This new way of dealing with building components has already brought into existence many new organizations in the U.S. The contributory industries have developed the necessary methods of dealing with the changes in the manufacture, distribution and transport. Let us only mention here three basic principles which are tabulated below. There are, of course, certain methods for partial prefabrication which can be regarded as a combination of these principles. The drawings at the heading of each paragraph are only intended to explain the basic feature of the assembly system, these are, however, drawn in the same scale to facilitate certain comparisons. (The radius of the circles forming the base of the drawings represent 6½ ft.)

1.—Wall-unit Principle

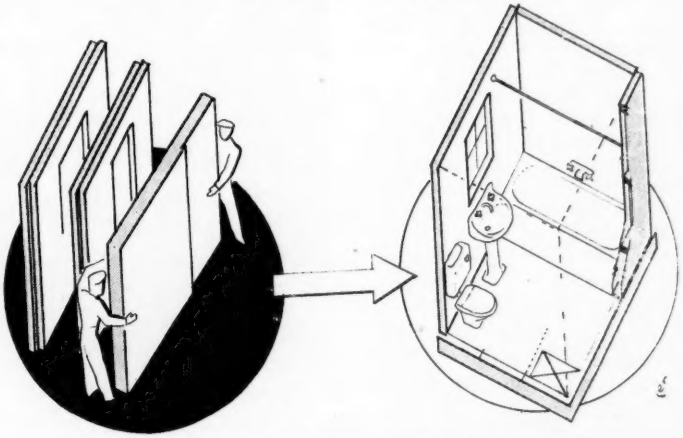


Fig. 3.—Prefabrication of bathroom based on prepared panels.

This system corresponds to the traditional methods of building wooden houses, with the difference that wall units are made up into panels in the factory instead of erecting a framework and fixing the sheet surfaces on the job. There are innumerable systems of manufacturing such large, jointless wall units, not only on wooden joists. Practically all types of structural and sheet materials can be adapted to such purposes. The principle in itself offers no revolutionary advantages for the construction of a bathroom, over brick or slab-built walls, since the various fitments, such as the lavatory basin, bath, etc., still have to be attached and fixed on the site in much the same manner as is customary. The wall units include framing elements, cavities, insulating quilts between the two jointless surface sheets. These units can be superior, but also inferior, to ordinary brick-wall structures, depending on the prefabricators' specifications. Many improvements can be achieved, however, with this type of method—even for permanent buildings.

Some prefabricators prefer to provide entirely factory finished walls, with hard and durable surface. Wiring and plumbing are generally incorporated to some extent in these panels. All holes and fixing devices can be pre-arranged so that the attachment of fitments on the job is a safe and speedy affair. Those who have seen the film on the "Homosote" system (shown in the R.I.B.A. on October 21) will remember the impressive speed and apparent ease with which the bathroom fittings, doors and windows, have been attached to the walls. Actually most of the prefabricated buildings distributed at the present moment are built in a similar manner, as a combination of fairly large, horizontal and vertical panels. Our Fig. 4 illustrates the erection of a hut (for the M.O.W.P.) built entirely of large panel sections, and although this example is of a temporary building it may be of special interest to follow the durability tests of this structure which is definitely the lightest possible "stressed skin" building. The effectiveness of the whole structure entirely depends on the quality of the synthetic resin adhesives which have been used as the only means of bonding the thin internal frame members, and the two surface sheets of plywood.

Applications of Plastics

Plastics.—Apart from the early attempts such as the experimental use of "Vinylite" (1934) there are no all-plastic wall units, but there are many instances where plastics have been used in the prefabricator's workshop or factory in making larger wall units. The cementing of "Homosote" sheets to the wood-frame elements looks simple enough, but actually the timing and organization of that cementing operation is quite a tricky problem, as air-drying liquid adhesive has been used. In one of the Gunnison systems there are dry phenolic adhesives used and the whole wall units are bonded in large presses suitably heated. The surfacing sheets used by the prefabricators have mostly something of interest to the plastics industry, as these sheets are often surfaced with fabric-resin combinations. Large resin-bonded sheets in lengths up to 20 ft. are especially suited for prefabrication of the wall-unit type; such sheets are available with and without resin-bonded fabric surfaces. Prefabricated shower-compartments have been manufactured of wallboards treated with thermo-setting resins, but as the need for prefabricated buildings is on the increase, there are now several new

Fig. 4.—Erection of hut for M.O.W.P. from large panels.

brands of pre-finished boards on the U.S. market. The importance of the combination of wall boards with thermo-hardening resin surfaces has been analysed in more detail in the previous article (November, page 405). The writer has recommended earlier in these pages (April issue, p. 97) investigating the possibilities of a certain type of plastic-tile for prefabricated bathrooms. A plastic tile of similar design has since appeared on the market in the U.S. in a form and to a set of specifications which will certainly be developed further in the near future.

2.—Mechanical Units

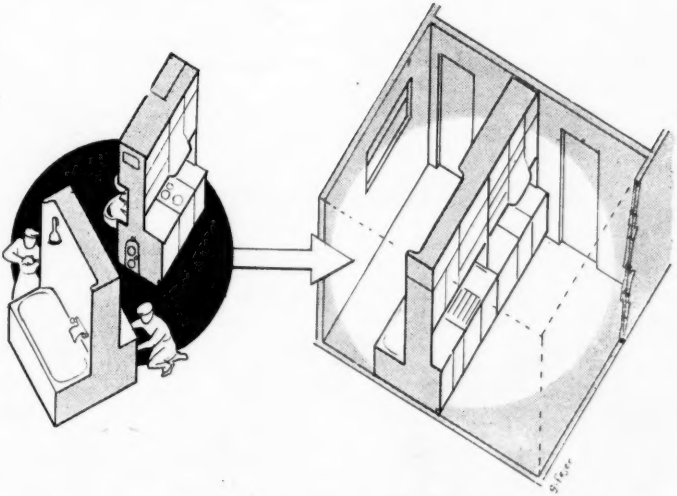


Fig. 5.—Prefabricated "mechanized" units of bathroom and kitchen.

This type of prefabrication is mainly intended to provide factory-made and factory-assembled units containing a number of serviced or mechanical parts. This has been suggested by the writer in the November issue of " Plastics " (page 403) for kitchen units, which can form part of either prefabricated or conventionally built structure. Since designing those units as a purely theoretic illustration there is some interesting evidence available now that this line of approach has been recommended by a number of other designers. One of the systems now going into production has been designed by W. D. Teague. His main idea is to turn the partition wall between the kitchen and bathroom into a " highly mechanized " unit containing all the necessary fitments for both rooms. Fig. 5 shows a sketch of this principle, but applied to the writer's earlier suggestion as exact details of the Teague system are not yet at hand. It will be realized that the principle of building the whole house around this kitchen-bathroom partition is advantageous from the point of view of economy in plumbing, heating, etc., but the variations in plan are limited, and the arrangement is likely to cause some loss of space in the layout. The Teague unit will not be available for individual users, only for the licensees of the company distributing the complete prefabricated buildings, for which this mechanical unit has been designed.

A special issue of the " Architectural Forum " (September, 1942) deals with a series of contributions of prominent American designers and architects towards the problems of the " House of 194x," and it is interesting to note that there are several suggestions for the design of such mechanical units. The unit suggested by Ralph Rayson and D. B. Runnels is based on similar principles as the Teague unit, although the feasibility of this " mechanical " partition of approximately 6 ft. by 14 ft. may be questioned. Another similar suggestion comes from W. Bogner, who designed a " mechanical " bathroom-partition unit.

Application of Plastics

Plastics.—Such units are eminently suitable for any light and tough material which can be formed into bent and shaped panels, as well as light skeleton structures. Both the aspects of plastic skeleton structures and shaped panels have already been described ("Plastics," November, pp. 404 and 406) in more detail in connection with kitchen units.

It is interesting to note that in the plans and suggestions for the "House of 194x"[3] the designers show a great deal of plastic-mindedness even when designing transparent shower partitions, although it is never specified what kind of plastic is to be used.

3.—The Whole Bathroom as a Unit

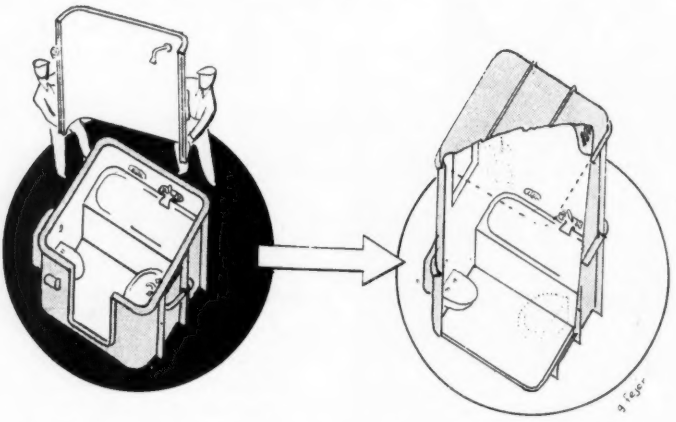


Fig. 6.—The construction and erection of small bathrooms of the unit type.

This principle has been carried out by prefabricators, although it has not yet been possible to produce many of these bathrooms on a really large scale. It is a perfectly sound principle to build the bathrooms as independent sections, their floors and walls as water and steam-proof as in the case of a storage tank. The measurements of a small bathroom permit the making of such structures even in one transportable piece, although it is obvious that transport in, say, three or four sections would make handling easier.

Illustrations Figs. 1 and 2 are examples of this principle, both designed by G. Sakier for a New York firm. A very interesting solution is the so-called "Five-by-five" bathroom, which can be regarded as the minimum space for a bathroom, as the actual ground space required is 5 ft. by 5 ft. Fig. 7 shows the base unit of this "Integrated Bathroom" made by Phelps Dodge. The designer, Buckminster-Fuller, has managed to place all installation units in a logical manner into this small space. The whole room is subdivided into two chambers, one containing the bath, the other the w.c. and lavatory basin. The base unit is stamped out of a copper sheet and, after receiving a factory finish, shows no joints or cracks. This section is about 2 ft. 6 ins. high and can be easily transported. When the further selections are attached the whole bathroom forms an enclosed unit weighing approximately 250 lb. only. This bathroom has been developed for ships and

places where the utmost economy of space is required.

Its greater merit is that it has led the way to an entirely new conception in prefabrication, although its original shape is not exactly pleasing. This bathroom was first manufactured five years ago,[2] and many designers have embarked on similar projects. Another, but larger and more luxurious type has been suggested recently by Maynard Lyndon, for an entirely self-contained bathroom which looks very much like a cylinder with a ground diameter of approximately 8 ft. This can be placed anywhere inside a single-storey building, as it has no window but a skylight and a ventilator on top of the cylinder.

Fig. 7.—Construction principles of the "Integrated Bathroom."

It is probably the "American Motohomes" system which is the earliest example of organizing prefabrication (1932) with such self-contained bathroom sections. The houses produced on the "Motohomes" system have separate bathroom, kitchen and laundry sections all arriving on the job in full working order. Since the first houses of this type have been produced by "American Houses Inc." there has been much development both in design, organization and in the quality of materials used, and the development still continues, with the aim of producing still better and cheaper units.

Plastics.—The structural conception of this type of prefabrication is very different from the two previous principles (1 and 2), as the tendency is to provide the bath, wash-hand basin, etc., as an integral part of the whole and not only to provide shaped panels, but to model the floors and wall fitments and even ceilings out of the same material. So far, shaped steel, copper and aluminium sheets have been used mainly for the formation of such structures. As mentioned before, the principle is one not unlike the formation of storage tanks, and the experience gained with plastics of building tanks and containers will be useful one day in this respect. The suitable medium in plastics which would lend itself to such intricate designs has not been fully developed yet. We have some indications, however, that thermosetting resins combined with asbestos cement and fibres will be developed further to meet the requirements of prefabrication.

Transport and Distribution

The prefabrication principles mentioned above under 1, 2 and 3 are only the main possibilities of the manner of assembly, but it will be realized that, in practice, the combination of such principles can be more effective, to suit the particular organization under which the bathrooms (or the whole buildings) are marketed and transported. This rough grouping of the systems under three major headings has been decided on only to simplify the subject, as literally hundreds of photographs and detail drawings would be necessary to deal fully with the analysis of the numerous systems known. One may object that the main aim of the American prefabricators during the past 10 years was (a) to provide small houses, (b) interiors for skyscraper structures, and (c) semi-temporary demountable buildings, and few of these aims are urgent problems outside the U.S. This is, however, only partly correct, as the significance of prefabrication goes farther than that, and it will gradually enter as an alternative method of construction in every country. It is a matter of distribution and transport which has to decide the limits of the factory assembly. The weight, size and packing specifications of the individual units transported are of

utmost importance. When studying the various organizations set up for the marketing of prefabricated structures, we find no uniform method of dealing with this problem. In most of the cases the existing distributive channels are used, so that the majority of the present marketing facilities will probably have a fair share in this line of business. It remains to be seen how far the foresight and intelligent organization of prefabricators can make use of the available services, and how far the present distributive agencies can modify their policy to undertake the distribution and servicing of prefabricated structures.

As far as the aspects of, say, assembled bathrooms in this country are concerned, it is unlikely that any major changes in the present state of affairs would be necessary, as both the transport facilities, distributors and local servicing agencies are capable of handling assembled structures.

The general public is not really concerned whether any part of the building is pre-assembled or not, as long as the general efficiency and durability of the particular structure is perfect. The present system of construction involves the need for frequent redecoration and overhauling, which have become a part of the policy of municipal and other building authorities. With factory-assembled and prefinished structures these periods could be greatly extended.

The Components of the Bathroom

Whatever the method of assembly there are a number of components which deserve some attention, as the main interest of the contributory industries is to provide the mass-produced equipment and components. The only difference which workshop assembly will certainly bring about is that lighter and tougher components will be needed than in the conventional construction of bathrooms. As the writer has made a number of suggestions for similar components earlier, only a few remarks and references are given here to each particular item.

Plumbing.—The research in plastics is just about to produce certain improvements upon the traditional methods of domestic plumbing. The tendency to save metal has started this type of research in Germany, long before the war, but the use of plastics should have as its only real aim the bringing about of technical improvements. To-day, the technique of using laminated plastic tubes in practically unlimited range of diameters and small-section tubing (extruded) is making great advances. There are no urgent reasons for adopting plastics to a large extent, but certain parts of the tubing system could be made of plastics to-day, if necessary. The cold-water system may be conceived in thermoplastics (such as vinyl polymers),[4] welded together with the plastic "torch-welding" process.[5] Hot-water pipes, waste pipes are possible in certain thermo-setting resins. Prefabrication makes it possible to have the exact plans ready at the time when the thermo-setting tubing is manufactured. Vent pipes could be made by a number of commercially available plastic tubes with slight modifications.

Baths, Lavatory Basins, etc.—Sanitary appliances of this type constitute another group of tough problems for plastics technicians. The constant action of warm water and proprietary cleaners on the plastic surface is bound to affect the appearance in time. The surface would be probably more durable and harder than the old types of varnished fitment but less durable than glazed steel or china. Children's baths, small showers, etc., can be made without difficulty, but the quality of the finish would be somewhere half-way between varnished paper mâché and the customary vitreous enamels, and this seems to impose a serious limitation upon the uses of plastics in this connection. What is more promising, however, is that plastics could be used for the design of, say, lavatory basins as supports and surrounds of a simple bowl made of some other material.

Spouts, Taps, etc.—The aspects of thermoplastic taps have been described in these pages earlier,[4] and references to the uses of thermosetting (cast phenolic) taps

and tap parts have been mentioned in some detail.[6, 7] The spouts for baths, shower-sprays, etc., moulded of, say, urea-resin, will probably become very popular, as these can certainly save a lot of cleaning and polishing time.

Lavatory Seats.—Plastic lavatory seats of both the thermosetting moulded or cast varieties and thermoplastic-shaped types are so widely known that these need no further comment; in fact, plastics are practically without rivals for this application.

Cistern Swimmers.—The suitability of a large number of plastics has been studied in the past for this application. Apparently practically all the main types of thermoplastics are adaptable, and one of the most economical solutions is to use cellulose nitrate sheet material blown with dry heat to the required shape. Numbers of sound designs of moulded phenolics are also known and it is likely that some of these components will be found at least as serviceable as the usual types, whether metals are in short supply or not.

Bathroom Cabinets.—The small cupboards fitted into the wall surface, if made of a suitable plastic, would have a better and more durable finish than the painted ones now generally used. Apart from this smaller cabinet (which could be made either by moulding or shaping from sheets) there are larger cupboards also needed in bathrooms, and these should form a part of the general layout. These cupboards should contain a space for soiled linen and several further compartments, and should be extended right up to the ceiling of the bathroom, to hold the innumerable articles which are kept there. The structure and finish of such a cabinet would be the same as the shaped wall panels. Supposing that resin-bonded, plastic-finished plywood is being used as panels, the cupboard would be formed from shaped sheets of the same type, and fitted into the scheme of the bathroom assembly.

Bathroom Windows.—Moulded windows for kitchen and bathroom have been suggested[8] earlier. The difficulties have been pointed out in some detail[9] dealing mostly with the present economic side of the question. Pullman windows and motorcar windows made of plastics are available, and it may be only a matter of time before windows and surrounds for domestic uses make their appearance.

Shower Curtains.—The advances made in the manufacturing of pliable plastic filaments, plastic treated fabrics, and pliable plastic films makes one feel that shower curtains will become a more or less plastic affair altogether.

Air Inlets and Air Heaters.—The surrounds for air heaters could be made in plastics of similar type to the wall-panelling, and preferably flush with the wall surface. The air inlets and perforated panels of several prefabricated bathrooms are already reported to be made of plastics.

Towel and Handrails.—If there is an air heater and sufficient ventilation, a number of plastic towel-rails is certainly as good a solution as a heated towel-rail. There are plenty of suitable phenolic and urea tubes already used for that purpose. In many of the modern bathrooms handrails are being fitted near the bathtub, which is certainly a helpful accessory, especially for elderly people. Plastics offer some products for the making of such handrails.

Laundering Equipment. — Bathrooms which belong to Group 3, according to their number of assembly, are likely to be of the minimum size, but those under Groups 1 and 2 are not necessarily small bathrooms, and it may be possible to incorporate facilities for laundering. It is unlikely, however, that bathrooms, complete with washing machines, wringers, etc., will be assembled in large quantities, as this may not meet the average demand. On the other hand, several housing experts have pointed out that if there is no other choice than kitchen or bathroom for washing and drying clothes the bathroom is the place better suited for the purpose. (In the majority of the housing schemes built both by the municipalities and private enterprise it is generally the other way round.) There are strong arguments on both sides, but

there may be a middle way by providing smaller bathrooms and with only sufficient equipment for laundering small articles. For this, the space above the bath tub can be utilized for fitting a clothes-drier, a principle which has been adopted in many of the L.C.C. schemes. Such things can be ugly or neat, depending upon the material used in making them. It is not difficult to visualize how clothes-driers could be made more effective and definitely better looking by using certain types of plastics. Another auxiliary (or supplementary) fitment is the ironing-board. In certain housing schemes it is pre-arranged that a teak board can be placed over the bath-tub. This may not be an ideal solution, but better than providing no alternative at all.

Lighting Units.—In prefabricated wall or ceiling sections the lighting fitments can be arranged sunk into the surface. Simple, trough-shaped reflector surfaces made of thermosetting plastics could be used for this purpose with a glazed front flush with the wall surface. This idea was illustrated by a sketch which appeared on these pages.[8] Incidentally, a lighting unit similar to that sketched is being manufactured now in the U.S.

REFERENCES

(1) "*Housing*," *by the Building Centre Committee, Vol. I.* **(2)** "*Architectural Record*," *Jan.*, 1937, *p.* 108. **(3)** "*Architectural Forum*," *Sept.*, 1942. **(4)** "*Plastics*," *Nov.*, 1942, *pp.* 380-383. **(5)** "*Plastics*," *Nov.*, 1942, *p.* 408; *also V.D.I. Report* 2,006. **(6)** "*Plastics*," *Nov.*, 1942, *pp.* 396-407. **(7)** "*The Architects' Journal*," *Oct.* 29, 1942, *p.* 284. **(8)** "*Plastics*," *May*, 1942. **(9)** "*Plastics*," *Oct.*, 1942.

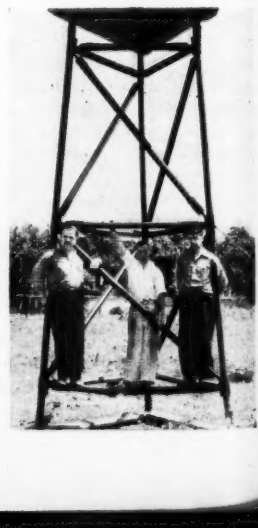
Pipe Lines

Structural units made of resin-bonded fibre paper in tubular form have been announced by H. W. Richter, Consultant to Federal Electric Co., U.S.A., in the September issue of "Modern Plastics."

The tube is made by wrapping vinyl-resin-treated paper on a mandrel, the preformed material then being transferred to the specially constructed press carrying a mould over 10 ft. long, equipped with a second mandrel over which the preform is slipped. The finished tubing, known as Fedralite, is 10 ft. long, with an outside diameter of 3 ins. and wall thickness of ⅛ in.

The tubes are noteworthy for their strength and water-resistance, the minimum "burst-point" tested under hydraulic pressure is about 200 lb. per sq. in. Higher results can also be obtained with specially made tubes. The tubing is being employed in the construction of low-pressure oil or petrol pipe lines and as shot-hole casing.

The specific gravity of the material is 1.35 and both tensile and compressive strengths about 10,000 lb./sq. in.



Fedralite tubing employed as a tank support.

INQUIRIES AND ANSWERS

(In Which is Included General Correspondence)

IMPORTANT NOTICE: If inquirers wish to receive replies by post, a stamped and addressed envelope must be included in their letter. Unless otherwise stipulated, it is understood that the submission of a problem to the Editor permits its publication in this journal.

The Electrostatic Charge on Instrument Covers

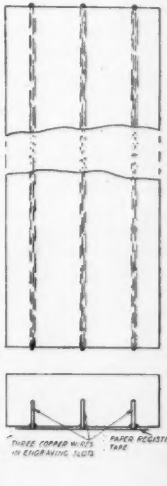
In the June issue of "Plastics," page 187, a letter from the Sifam Instrument Co., Ltd., pointed out the uselessness of plastics for instrument windows and its shortcomings in other applications, due to the ease with which plastic materials such as Perspex and Rhodoid acquire an electrostatic charge by friction.

This property is admitted by all users of plastics. In many applications its influences are of no consequence; in many of those where the electrostatic charge is objectionable, the resultant disadvantages have been overcome or offset; in a few, the difficulties encountered have not been overcome, and it is granted that in such circumstances the materials concerned are "useless"—but only until the answer is found. It is felt, therefore, that the condemnation of plastics due to electrostatic charging should be interpreted as stressing one of their shortcomings, a feature that might with advantage have been included in the original note, and not as a general condemnation of them for instrument work. The number of applications in which they are used for windows, for opaque, transparent and translucent scales, for delicate electrical instruments gives one the impression that the number of instances where they are quite unsuitable is very small.

The Editor's note upon the possibilities of modified resins produced by the inclusion of organo-metallic compounds is extremely interesting and has real possibilities. The retention of the static charge by cellulose acetate and methyl methacrylate under humid conditions better than it is retained by glass can presumably only be explained by virtue of the metallic silicate nature of glass. It is known that glass can "ionize" not only on its surface but also through its mass, and a material of this nature would discharge more readily under damp conditions than an electrolytically inert one. The possibilities of including organic metal salts in the plastic, e.g., zinc or aluminium stearates or oleales, or in a surface coating to the plastics are, therefore, very promising.

Metal powders have been dispersed in cellulose acetate and in cast phenolic resin without influence upon this electrostatic property, due undoubtedly to lack of continuity of the conducting path. A smear of glycerine over surfaces concerned is a specific method for overcoming the trouble; it is by no means generally applicable.

A mechanical method of overcoming electrostatic trouble is recorded as of interest. The case is that of an electrical message-recording instrument in which the paper tape is travelled immediately beneath a Perspex window. The latter is 3/32 in. thick and about 3 ins. wide and 12 ins. long. Difficulties arose due to the traverse of the paper charging the plastic window, being attracted to it, and adhering so that travel stopped. A number of methods for overcoming the trouble were examined. Actually, the window upon its underside (contacting the paper tape) had three spaced lines longitudinally engraved upon it



Mechanical method of overcoming static electricity.

and filled-in black. Advantage was taken of this, and three thin copper wires were laid in these engravings, lightly cemented in position with nitrocellulose adhesive, their ends turned around and secured to the end edges of the window. By this means, the travelling paper was separated from the plastic window by a gap a few thousandths of an inch wide. This solution proved entirely satisfactory. A sketch illustrating this problem is given in Fig. 1.

The foregoing example is cited not to condone the practice of ignoring a fundamental fault, but to demonstrate that the advantageous features of a material need not necessarily be lost due to one drawback, and that it is possible often to get around the difficulty. One is reminded of a similar situation when coil winders were first asked to use 0.001-in. thick cellulose acetate film in place of glascine-type paper of the same thickness for interleaving small coils, feeding it from automatic machines. It proved to be an impossibility due to "static," but by modifications to the feed system shops in America and on the Continent proved it could be done and were soon taking advantage of the film 0.0005/7 in. in thickness that became available. Practices in this country began to follow suit.

It is hoped that these notes are not interpreted as an intention to damp criticism of the written word; they are only intended to stress that the criticism levelled was of restricted validity.

E. E. HALLS.

EDITOR'S NOTE.—We are, of course, in thorough agreement with the writer in his opening sentiments, although we are sure the inquirers did not infer that the plastics named were generally useless. They are, of course, of no use untreated for the purpose described. As for our own suggestion that metallic organic material could be incorporated with advantage in the plastics named, we should like to point out that while, say, zinc, lead and magnesium naphthenates, oleates, etc., will remove static electricity, it is highly probable that conductivity is not so much due to the nature of the compounds themselves but also due to the fact that they invariably contain small quantities of water. This does not affect their transparency. This is due to the fact that, under normal conditions of manufacture, it is almost impossible to remove all water (and, indeed, all inorganic salts). Furthermore, we should like to point out that it was not intended to apply these metallic organic compounds as a surface film, although this can be done quite easily, but to incorporate them with the plastic prior to moulding, etc. Zinc, lead and aluminium naphthenates, for example, are far too soft for exterior application, although calcium naphthenate is quite hard and tough. Oleates and stearates are also soft and are somewhat mechanically weaker than the corresponding naphthenates.

Plastics in Building Structures

We notice in your November issue a paragraph headed "Curtain Rails" (page 400—in the article "Plastics in Assembled Building Structures," by G. Fejér. This paragraph states that "thermo-hardening rails cannot be bent at the overlaps . . ." and that "special sections have been produced to overcome this difficulty . . . composed of two rails instead of one."

It is true that a two-rail section was produced in Germany, but we would point out that, although extruded curtain rail profiles manufactured by our subsidiary Extruded Plastics, Ltd., from "Rockite" phenolic moulding compounds cannot be bent on site, they can be bent during the manufacturing process and an overlap arranged for single-track extruded "Rockite" curtain rails, thereby reducing the cost of providing two lines of rails across the width of a window when the double line is required for only, say, 4 ins. to 6 ins.

F. A. HUGHES AND CO., LTD.

Polyvinylidene Chloride

With reference to the articles in regard to "Saran" Vinylidene Chloride polymers of the Dow Chemical Co., which you published in some of your issues, notably January, 1942, we would like to advise you that we are now in a position to quote for priority work.

We shall, therefore, be much obliged if you will kindly refer to us any inquiry which you may receive.

R. W. GREEFF AND CO., LTD.

PRODUCTION NEWS

Raw Materials, New Plant, Works Organization, Control Apparatus, Research, Personal and Trade Notes

SMALL CAPACITY REDUCING VALVES.—For use with compressed air, steam and water, much interest attaches to a small capacity reducing valve made by Hopkinsons, Ltd., being of the direct-acting type, simple in construction and characterized by the firm's usual high-grade workmanship, on the same lines as their range of larger reducing valves of the well-known relay-operated type. This small valve, in the form of a vertical cylindrical closed casing, has a ½-in. inlet (gas thread) and is generally fitted also with a self-contained relief valve so as to prevent any overpressure in the low-pressure side.

Essentially, the principle is that the degree of opening of the reducing valve is controlled by the low pressure exerted on the lower face of a diaphragm against the pressure of an adjustable loading spring operating on the upper face, the spring being set to the exact low pressure required. Any fall in the latter, therefore, results in the leading spring causing the valve to open to a corresponding extent until the passage of the compressed air (or other fluid) from the high-pressure or inlet side restores the low pressure to its predetermined figure. As soon as the latter is exceeded, the resistance of the loading spring is overcome and the valve again closes, and so on, a point of equilibrium being reached at which the valve is just sufficiently open to maintain a constant pressure on the low-pressure side.

The safety valve in the lower part of the cylindrical casing is also of the spring-loaded type, adjusted to release at any desired pressure, four circular ports in the casing being provided for the purpose as outlets. Both the lower or safety valve portion and the upper or pressure-reducing portion of the valve are also protected.

Further with regard to details of the construction, it may be stated the valve casing is of bronze, which also applies to the internal fittings, with the exception of the springs, which are of steel, and the valves and seats.

Index to " Plastics "

We beg to announce that copies of the Index to Volume 5 of " Plastics " are now available from this office at the price of 6d. each.

SUPERVISORS' DISCUSSION GROUP.—The last meeting of the autumn session of the N.E. London section of this group will be held at the South-west Essex Technical College, Walthamstow, on Tuesday, December 15, at 7 p.m., when Mr. W. Carrott, M.I.Chem.E., works manager of Messrs. Locke, Lancaster, and W. W. and R. Johnson, Ltd., will give a talk on " Waste Prevention." This will be followed by discussion. The opening meeting of the winter-spring session will take place at the above college on January 26, 1943. Further details will be announced later. All inquiries regarding membership of the above group should be addressed to Hon. Secretary, N.E. London Supervisors' Discussion Group, South-west Essex Technical College, Forest Road, London, E.17. Enrolment forms may be obtained on request.

INDUSTRIAL HOUSING.—It is now just 12 months since the committee for the Industrial and Scientific Provision of Housing was founded, and it is hoped that it will be possible to call a general meeting within the next few weeks.

The purpose of this meeting will be to report the progress of the work and to obtain approval for the reports and the next steps. This is occasioned by the fact that the initial work undertaken is now virtually complete. Many hundreds of systems of mechanized house production have been examined and some 300 of these, selected as being more practical or as having been actually employed, have been analysed in some detail, and a comprehensive system of reference devised for the data in our possession. This analysis, together with general technical observations, will form the subject matter of our first report.

Whilst this technical work has been in progress, investigations have been made by members of the committee and others into the wider problems confronting the application of mass-production technique to building. There are costing, economic and organizational difficulties and problems of æsthetics and public relations, the nature of which is not generally understood. Analyses of these will be published, together with suggestions as to the methods of deal-

ing with them. This second report will include the outline of a duly constituted body, its programme of work, its budget and means of raising the necessary finance.

TULLIS RUSSELL AND CO., LTD.—We are asked to inform our readers that the Rothmill Calendar will again be available this year at the nominal price of 3d. Orders, accompanied by stamps, can be sent to any of the four branches of Tullis Russell and Co., Ltd.

DE LA RUE PLASTICS, LTD.—The Board of Thomas De La Rue has announced that development has reached the stage when the plastics side of the business can be worked as a separate company. Accordingly a company with the title of De La Rue Plastics, Ltd., has been registered with an authorized capital of £1,000,000. No part of this capital will be offered for outside subscription. It will be a subsidiary wholly owned by Thomas De La Rue and Co. A second subsidiary entitled De La Rue Stationers, Ltd., has also been formed to deal with that side of the business making playing cards, fountain pens, etc. The authorized capital of this company is £100,000.

PLASTICS CONTROL.—We regret to hear that Mr. C. H. Glassey has resigned his post on Plastics Control through ill-health. Mr. G. W. Thomas, formerly of I.C.I. (Plastics), Ltd., has been appointed Deputy Controller and commenced his duties on November 16 last.

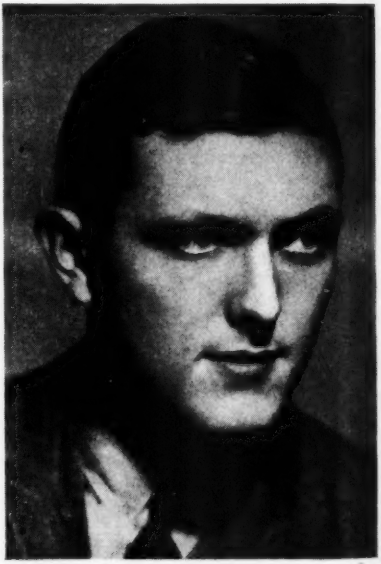
WASTE PAPER EXHIBITION.—So great has been the demand for the Waste Paper Recovery Association's exhibition "Design for Economy—Paper in Battledress," recently on view at the Savoy Hotel, that the Directors of the Ford Motor Company have kindly lent their showrooms in Regent Street, London, W.1, so that the exhibition may be shown to the public. It will be on view for a limited period from December 3 from 10 a.m. to 4 p.m. on weekdays and from 10 to 1 on Saturdays.

The exhibition, to which some 200 business firms, Government departments and public utility concerns have contributed, will contain several new exhibits.

HOME TRADE REGISTER.—The revised Home Trade Register of manufacturers, wholesalers and mercantile agents, registered under the Limitation of Supplies (Miscellaneous) (No. 16) Order, 1942, has now been published, and can be purchased from H.M. Stationery Office at the following addresses:—York House, Kingsway, W.C.2; 120, George Street, Edinburgh, 2; 39-41, King Street, Manchester.

ERRATA

In the article entitled "Dispersions of Rubber," by Dr. H. J. Stern, published on p. 375 of our October issue, the sub-heading made reference to the "Beken Duplex Mixture." This should have been the "Beken Duplex Mixer," which plant is now so widely used for making dispersions of rubber and rubber-like plastics. The original typescript included references to the literature on the subject, but had been excluded in reproduction. By an error, the number "10," making apparent reference to such literature, had been left in the article. We regret this oversight, which may have led to some confusion.



FLIGHT LIEUT. DENIS MANNERS-SPENCER. We regret to announce that Flight Lieut. Denis Manners-Spencer, R.A.F., who was at one time on the advertisement staff of "Plastics," has been killed in the Middle East. Flight Lieut. Spencer was a keen athlete and good all-round sportsman, and had many friends in the Plastics Industry.

Resinoids and Other Plastics as Film Formers

By B. J. BRAJNIKOFF,
Consulting Electrical Engineer

XIV.—Applications of Electronic Theory to the Chemistry of Organic Combinations

THE concepts of the electronic nature of matter have lately begun to arouse a deep interest of a great many chemists. The modern notions of the structure of the atom, as postulated by J. J. Thomson, Rutherford, Bohr, Cossel and others, have recently been found to be of appreciable service in their application to the studying of the most-diversified problems, enabling the investigator to evolve a new and clearer view of chemical processes and to learn in detail their basic character.

Of special interest, from the chemical standpoint, is the study of the development of the reactions and the changes in the properties of a product that take place. These variations in the characteristics of the resultant substance occur necessarily with the alteration in the structure of the electronic envelope of at least one of the ions composing the molecule. Hence it follows that in order to clarify the motivating forces of the reaction course as well as the properties of the bodies formed, a great significance should be attached to elucidating the magnitude and sign of ionic charges.

For instance, in the so-called "electrodynamic" reactions, or oxidation-reduction processes, the structure of the electronic envelope of the discrete atoms undergoes change, with consequential simultaneous alteration of the charge or its sign, or both the sign and the charge of the atoms.

Before we proceed to the discussion of the characteristic features of various high molecular compounds, as typified by resinoids and other plastics, and their differences as reflected in the ability for electronic regroupings, it is instructive to approach the problems of crystallization, fusibility and solubility a little more closely.

To illustrate the points raised in the preceding section, let us take, for example, the molecule of sodium chloride.

Illustrative Examples

In this molecule the constituent atoms are rather strongly distinct in their electrochemical nature.

For this reason in the molecule NaCl the degrees of the proximity and the interval of the attachment of the valence electrons in the atom-acceptor are much greater than those in the atom-donor. Thus the molecule NaCl possesses a strong electronic structure with very difficultly transformable charges and strong ionic properties.

Its valence bonds are thus very stable and display, therefore, very small bonding capacity. That is why, on the one hand, the molecules NaCl show a strong tendency for crystallization and are characterized by the great speed of the crystallizing process, and, on the other hand, the crystals of NaCl are not very hard and are easily soluble and fusible.

In the molecule SiC (carborundum) the electrochemical nature of the distinction between its constituent atoms is far less pronounced than in the molecule NaCl. For this reason the molecule SiC has a rather highly mobile electronic structure, with very feeble predominance in the spatial distribution of charges, with the result that its ionic features should be very weakly expressed. If the molecule SiC is ionized to a far less degree than the molecule NaCl, the valence bonds

of the molecule SiC are much less stable than those of the molecule NaCl. It is evident, then, that the bonding capacity of the valence forces of the molecules SiC is much higher than that of the molecules NaCl.

Consequently, the ability for crystallization of the molecules SiC should be much less than in the molecules NaCl. Parallel with this, the stability of the crystals SiC should be much higher than that of the crystals NaCl. As is known, although the crystallization of the molecules SiC proceeds with a much greater difficulty than that of NaCl, the stability of the crystals SiC considerably exceed the stability of the crystals NaCl.

The difference in the electrochemical nature between discrete atoms of carbon is, naturally, still less than between separate atoms of carbon and silicon. Accordingly, the electronic structure of the diamond is still considerably more mobile than that of carborundum.

Thus, in the diamond the regrouping of the electrons causes still greater disturbance in the symmetry of spatial arrangement of atoms than even that in the carborundum. At the same time, the valence bonds of the diamond atoms are considerably less stable, and, consequently, possess a greater bonding power than those in the carborundum atoms. This shows the reason as to why, with a more difficult crystallization of the diamond, its crystalline structure is of greater stability than that of carborundum.

Molecular Structure in Relation to Properties

In the qualitative sense, the properties of molecules are distinct from the properties of the constituent atoms—they are not equivalent to a mere sum total of the properties of the component atoms. Already Berzelius[175] put forward a suggestion to classify chemical combinations according to different orders, i.e., according to series: atoms, molecules, complexes, etc. Academician N. C. Kurnakoff[176] arrived at the analogous conclusions, which have been enunciated by him at the fourth Mendeleeff Congress, in 1925, viz., electrons $\rightleftharpoons$ elements $\rightleftharpoons$ molecules $\rightleftharpoons$ solutions.

The natural and rational classification of chemical compounds should give a molecule as such, with all its properties, and depict its structure, i.e., the arrangement of discrete atoms, and groups, the architecture of their electronic envelopes, and the mutual influence of these envelopes.

As far back as 1883 Pelopidas[177] indicated the analogy observed between a period in the Mendeleeff's system and a number of radicals, for instance, from C_6H_{13} to C_6H_6 and from CH_2NH_2 to CN.

In 1907, Morozoff,[178] in his "Periodic System of the Structure of Matter," had developed for organic compounds tables similar to those of the periodic system.

With the discovery of the atomic number of a chemical element, several attempts have been made to apply this fruitful concept to molecules and radicals, for instance, by Miro,[179] Grimm,[180] Tibyrica,[181] and Shemjakin.[182]

Accordingly, any chemical combination can be expressed by a formula $R_mR'_nR''_p$, where R, R', R'' . . . are the atomic numbers of elements, and the subscripts m, n, p the number of atoms of each kind. With the one given variable, we thus obtain a geometrical row of combinations; with the two variables we get the table; a further development of the idea of the geometrical row leads to its arrangement in space; thus the three variables produce a three-dimensional arrangement, and n number of variables a corresponding n-dimensional system. The molecular number is determined as the sum $R_m + R'_n + R''_p = M_N$

For organic combinations, special significance attaches to the structural factor, which is easily defined by the introduction of a new concept—the "characteristic structural number." On the basis of identical structural number, isomers for a given molecule are divided into several groups. A general expression for the structural number is $Q^l_m R^k_n S^l_p$ . . ., where Q, R, S denote atomic numbers of various chemical elements, for example,

carbon, oxygen, fluorine, etc., and i, k, l . . .—the number of hydrogen atoms attached to them; m, n, p . . . stand for the number of atoms Q, R, S.

It may readily be seen that the notion of "structural numbers" quantitatively determines the combination of atomic groups constituting a given molecule, and allows us to draw an easy comparison of various physical properties of organic compounds.

The aim of the natural classification of chemical combinations is, essentially, the problem of building a space-lattice, all the "singular points" (lattice points) of which are clearly distinct, that is, conform to the different (physically and chemically) molecules. It is exactly opposite to the space-lattice studied in the crystallography, where all the lattice-points are identical.

The complete system should account for the interaction of the molecules with atoms and electrons, on the one hand, and micelles and more complex units, on the other hand.

The natural classification arranges the molecules according to their molecular and structural number and portrays molecules in their similarity and difference, mutual bond and interaction with other molecules, the aggregates of other orders. Each molecule is viewed here as a material "singular point" of the space-lattice. Thus the entire system may be characterized as the spatial diagram of various properties (viz., boiling points, specific gravities, refractive indexes, etc.), i.e., as a special variety of physico-chemical analysis.

Every "singular point," the molecule, in its interaction with various points surrounding it, determines the properties of adjacent "chemical space," and promotes in it "singular folds" directed towards "singular points" surrounding it. For a number of properties there may be observed the invariance of the above folds (for example, b.p. sp. gravities, coefficients of refraction, in the same state of aggregation), due to the peculiarity of molecular structure.

The specifically different properties of the molecules, as distinct from those of the composing atoms, are testified by molecular spectra, Petrenko-Kritchenko[183] periodic law, etc.

The main thesis of the periodicity law, as postulated by Petrenko-Kritchenko, is that the accumulation and approach of identical atoms or atomic groups in the molecule promotes the alteration of their mutual influence, which may drop to zero and pass into the opposite. This postulate is of great interest and importance in application to colloidal systems, solutions, and the like.

The explanation of this law is possible only on the basis of studying the peculiarities of the molecular structure, which the quantum chemistry will unfold before us in the future.

Hence, the natural system of molecules may be described as a generalized diagram of the properties arranged in accordance with the molecular and structural number and the molecular symmetry. In a normal geometrical row each molecule can be characterized by a symbol which determines the mutual connection of its "singular points." The comparison of molecules in the system permits us to draw a number of conclusions and predictions with regard to their physical and chemical properties.

The Electronic Theory of Organic Chemical Compounds

At the basis of the electronic theory of the structure of organic combinations, as developed and verified (in many instances) by experiments during the past three decades by the school of Professor A. M. Berkenheim[184] in Russia, is the thesis that in the formation of a simple bond between the two carbon atoms, one valence electron from each of them moves in the direction of another atom; both moving electrons, on leaving their original loci, stop between the two atoms at equal distances from both, if the two carbon atoms possess identical charges, and at unequal distance, when the interacting atoms have different charges. In the latter case the electrons approach

nearer to a more stable carbon atom and stop farther from a less stable one, each being at different distances from the respective atom. In the process, a more stable atom proves to be that of the atoms which is able to retain a greater number of its own valence electrons, and towards which move more electrons from other interacting atoms.

In the double and triple bonds there move two or three electrons respectively from one less stable carbon system to another more stable one. It is easy to see that in this movement of valence carbon electrons we have something quite similar to a general process taking place in the formation of compound from the two different atoms of any chemical elements; the valence electrons of the less stable elementary atom are always moving towards the atomic system of another more stable element, in which event also a greater stability is shown by the atom of an element that is richer in the valence electrons, and a lesser stability displayed by the atom of an element possessing inferior numbers of the valence electrons.

Examples of Electronic Regrouping

Both types of electronic regroupings may be illustrated by the following examples.

In effecting the union between the sodium atom and that of chlorine, the valence electron of the former finally passes into the system of the chlorine atom, thus forming $\overset{+}{Na}$ ion and $\bar{Cl}$ ion, which are subsequently bonded by electrostatic forces; in the formation of the bond between the nitrogen and oxygen atoms, the valence electrons of the first move nearer to the atomic system of the second element, without, however, being entirely incorporated into the latter.

Whether the valence electrons of one atom were completely transferred to another, forming ions, or merely moved farther from the system of this atom, approaching nearer the system of the foreign atom, the Berkenheim's School proposed to call, conditionally, the atom from which the electrons migrated, the positive ion; the atom towards which these electrons travelled is the negative ion.

The number of moved electrons and the resultant positive electric charges may be symbolized, in place of so many plus signs, by the corresponding number of points, and the number of the electrons approached to the system can be denoted, instead of the minus signs, by the vertical dashes. Thus the molecules of sodium chloride, carbon monoxide or carbon dioxide, etc., may be expressed in the following fashion:

$$Na{\cdot}Cl', \quad C{\cdot\cdot}O'', \quad C{\cdot\cdot\cdot\cdot}O_2'', \text{ etc.}$$

It is very easy to see how on this basis the formulæ of organic combinations can be written; to illustrate by example, let us examine the acetic acid,

$$C'''H_3C{\cdot\cdot\cdot\cdot}O''O''H,$$

and nitromethane

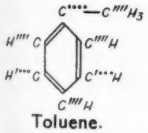
$$C'''H_3N{\cdot\cdot\cdot\cdot\cdot}O_2''.$$

Indeed, the electrons of the three hydrogen atoms of the methyl group moved towards the first of the carbon atoms of the molecule of acetic acid, and on the contrary, the electrons of the second carbon atom of the same molecule travelled nearer to the respective atoms of oxygen; consequently, in the formation of bond between both carbon atoms, the first of them that added to its own four electrons, the three foreign ones from the three hydrogen atoms, should draw within its system also the electron from the second carbon atom, which may be regarded as deprived of its valence electrons that moved to both oxygen atoms; hence it is obvious that the first carbon atom may be denoted in the form C'''', and the second as $C{\cdot\cdot\cdot\cdot}$.

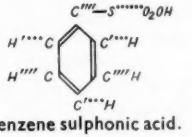
We have an analogous position in the molecule of nitromethane; it is clear that the four valence electrons of the nitrogen atom travel towards the two oxygen atoms, whence it follows that the fifth electron that remains in the system of the nitrogen atom also moves towards the carbon atom of the methyl group, and this carbon atom forms the system C''''. In the same way may be observed the sequence of the electric charges in the molecule of toluol.

Furthermore, it follows that in the molecule of ethane each of both carbon atoms received the three electrons from the three hydrogen atoms, again conditionally, assuming the electrons moved towards the carbon atoms from the hydrogen atoms as already belonging to the carbon atoms, which, strictly speaking, is not correct, since these electrons are still, as it were, the common property of atoms of carbon and the hydrogen atom. The fourth electrons of both carbon atoms, in the process of formation of ethane molecule, could stop between both carbon atoms, equidistant from each. According to Berkenheim, however, the molecule of ethane may be represented as $C'''H_3—C'''H_3$.

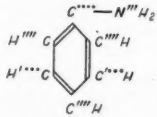
The above-described considerations afford the possibility of quickly expressing any formula of organic combinations; thus, for example, the molecules of toluene, benzene sulphonic acid, aniline, should be represented in the following manner:—



Toluene.



Benzene sulphonic acid.



Aniline.

The Relationship Between the Electronic Structure and Properties of Plastics

Let us now examine the relationship existing between the structure and characteristic properties of high polymeric organic compounds, such as typified, for example, by resinoids and other plastics.

The high molecular organic substances in the majority of cases represent the polymers of weakly ionized and, at the same time, strongly unsaturated molecules of the type of styrol, indene, coumarone, and the like.

On the one hand, the great mobility of the electronic structure of synthetic resins and other plastic materials, strongly reduces their ability for crystallization, and, on the other hand, a great bonding power of their double bonds imparts to them accentuated hardness and stability.

The above considerations indicate that the internal mechanism of the organic polymers is ill adapted for developing crystalline structures, but they show also that, if they do form the crystalline nuclei as well as their crystalline structures (as, for instance, polyvinylidene chloride), the latter should possess a very great stability.

The stabilization of the electronic structure of the molecules leads to the increase in the symmetry of the atomic arrangement in space. Consequently, the development of crystallization within the organic polymers should grow parallel with the stabilization of the electronic structure of their molecules.

The electronic structure of the molecule of the vinylbromide,

$$\left[\bar{\mathrm{Br}} \longleftarrow \overset{+}{\mathrm{C}}\mathrm{H} \rightleftarrows \bar{\mathrm{C}}\mathrm{H}_2 \right]$$

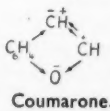
in consequence of the strong difference in the electrochemical nature of the atoms of carbon and bromine, are far more stable than the molecule styrene,

$$\left[\mathrm{C_6H_5} \longleftarrow \overset{+}{\mathrm{C}}\mathrm{H} \rightleftarrows \bar{\mathrm{C}}\mathrm{H}_2 \right]$$

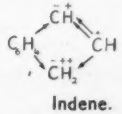
Due to this circumstance, the polymers of the vinylbromide should possess considerably greater capacity for crystallization than the polymers of styrol, and, therefore, the crystalline structure in polymers of vinylbromide should be expressed in a much higher degree than that in the polymers of styrene.

Indeed, as has been shown by the Röntgenographic studies, the polyvinylbromide, in contradistinction to polystyrene, has a clearly defined crystalline structure.[171]

We now pass on to the molecules of coumarone and indene:—



Coumarone.



Indene.

The distinction in the electrochemical nature of the atoms of oxygen and carbon is expressed appreciably stronger than between the separate atoms of carbon.

Thus, the electronic structure of the coumarone molecule is considerably more stable than the molecule of indene. Hence it follows that the change of the atomic charges in the molecule of coumarone is effected with a far greater difficulty than that in the molecule of indene.

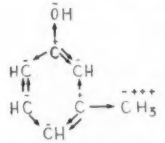
The foregoing considerations show that polymers of coumarone possess crystallizing ability to a higher degree than polymers of indene, and, consequently, crystallization in the former is considerably greater than that in the latter.

At the same time, the bonds within the indene polymers are appreciably stronger than those within the polymers of coumarone. That is why the indene polymers are much more difficultly fusible and soluble than those of coumarone.[172]

Condensation Products from the Electronic Viewpoint

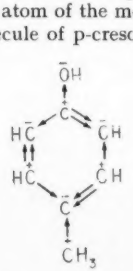
The resinoids of the Novolack type represent the products of the condensation of para-cresol with formaldehyde. The resol resins are formed by condensing formaldehyde with meta-cresol.

In the molecule of m-cresol,



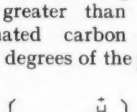
the electrons of the valence bond C – CH_3 are distributed predominantly in the carbon atom of the methyl group.

In the molecule of p-cresol,



the electrons of the valence group C – CH_3 are arranged predominantly in the non-hydrogenated carbon atom.

The magnitude of the negative charge of the carbon atom of the group is, naturally, much greater than that of the non-hydrogenated carbon atom, and, therefore, the degrees of the proximity and



the duration of attachment of electrons of valence bonds C – C in a non-hydrogenated carbon atom are much higher than in the carbon of the methyl group.

Thus, the electronic structure of the p-cresol molecule is considerably more stable than that of the molecule of m-cresol. Whence it follows that the molecule of p-cresol is ionized appreciably stronger than the molecule of m-cresol, whilst the bonding power of the valence bonds of m-cresol is much greater than that of p-cresol. In accordance with this, the resinoids of the Novolack type are much more capable of crystallizing than the resol resins.[173]

At the same time, the strength of the bonds between the molecules in the resol resins should be considerably greater than that in the Novolacks.

It is just this circumstance that provides an explanation as to why the Novolacks are fusible and easily soluble resins, while the resol resinoids are infusible and insoluble.

Thus, by promoting the change in the mobility of the electronic structure of the cresol molecules, we can modify the properties of the produced resins as well as the films and other compositions derived from them, and impart to the products other valuable technical characteristics.

Modification of Properties

In this way we can also modify the properties of the typical crystalline substances. As has been shown earlier, the molecules of NaCl possess a stable electronic structure, with a relatively constant

distribution of charges. If, then, under the influence of the extraneous factors, we will impart to NaCl molecules a more mobile electronic structure, with the more readily transformable charges, by this very means we will prevent the symmetrical arrangement of their atoms in space.

The stability of the valence bonds is the less, and their bonding power is the higher, the more mobile is the electronic structure of the molecule.

Consequently, by elevating the mobility of the electronic structure of NaCl molecules, we, on the one hand, lower their ionization, and, on the other hand, we augment the bonding power of their valence bonds. This gives rise to the braking effect upon the crystallization of NaCl, and the simultaneous increase in the strength of the bonds between atoms of polymers (gels and colloids).

This is the reason for the formation of the stable colloidal solutions and gels of NaCl, with feebly developed crystalline structure.[174]

Therefore, by varying the mobility of electronic structure of a substance, we are thus in a position to accomplish a complete reconstruction of its crystalline and amorphous nature.

Practical Aspects

One of the basic properties of matter, of which all the material bodies consist, is its divisibility. Since the solids offer great resistance to division, their molecules must be held together by attractive forces (the forces of cohesion) of considerable magnitude. At the same time, the fact that solids and liquids suffer change of volume only under great forces impels us to conclude that forces of repulsion also act between the molecules, keeping them apart at a certain distance. The attractive and repulsive forces arising from a molecule are only effective within a spherical region of the radius up to about 5×10^{-6} cm., known as the sphere of action. The attractive forces which cause the molecules composing the parts of different bodies to hold together are designated as forces of adhesion.

The fundamental function of a protective coating is the mechanical exclusion of the environment from the surface of a base material. The coating composition should provide a film that is highly resistant to scratching and has no tendency to curl, buckle, shrink or become brittle under the usual conditions incident to its use; moreover, while retaining its flexibility, if subjected to drastic temperature fluctuations (heat and frost), it must not be detachable from the substrate.

The factor of adhesion, therefore, is of prime importance, particularly in application to metals, since the molecular forces of the metallic surface are ready to interact with the electrical forces residing in the polar molecules of the film-forming medium. The lack of surface homogeneity, which is characteristic of commercial metals, provides the seat of electrochemical forces; the random distribution of anodic and cathodic point-lines gives rise to the flow of electric currents, resulting in attack of the substrate.

To prevent the formation of corrosion centres, the onset of which is evidenced by flaking, peeling of the film, etc., it is necessary to inhibit the closing of these minute currents, or the ionic conductance, by means of appropriate coating composition, capable of effecting an intimate contact and strong adherence to the surface.

In this respect the resinous materials, characterized by structural complexity of their molecules of the diverse kinds, sizes and shapes, and thus possessing varied fields of force, are peculiarly fitted to exert the bonding forces that are adequate for developing adhesion.

Action of the Surface Forces

As is known, the chemical and physical properties of gases, liquids and solid bodies undergo drastic changes in the immediate vicinity of a surface. It is of great theoretical and practical interest, therefore, to find out the order of distance over which extends the action of a surface. One of the notable contributions to this field, supported by ingenious experiments, belongs to Bowden.[185]

According to notions of the classical

physics, the molecular forces exert their influence over a great distance, so that a molecule can directly act upon another molecule over a distance of several thousand Angstrom units. From the point of view of the modern concepts of the nature of intermolecular forces it is difficult to conceive the mechanism of such a long-distance action. According to generally accepted notions, the molecules are bonded with one another either by the forces of dispersion, or by the electrostatic attraction. The latter factor can be evoked both by free charges and also through the interaction of the permanent or induced dipoles, but in either case the radius of action is very small, being of the order of merely a few Angstrom units.

Thus, it is reasonable to suppose that the surface action extends only to those molecules which are in immediate proximity to it, i.e., that the surface could not be expected to exert a direct influence upon the molecules, which are situated at a distance greater than several molecular diameters. It is possible, however, that the surface acts upon more remote molecules in an indirect manner. The first adsorbed layer can attract the second, the latter the third, etc., until long molecular chains are effectively bonded to the surface. Admittedly, in this way may be formed consecutive molecular layers, so that the presence of the surface alters the properties of a substance with which it is in contact over the distance of several thousand molecular diameters.

The experimental data concerning this question are related, chiefly, to the measurements of the thickness of adsorbed layers of gases and fluids at the boundary of the two phases, as well as the evaluation of mechanical properties of gases, liquids and solids in proximity to the surface.

Results of these investigations on the adsorption of gases and vapours upon the solid surfaces (a very full survey of which can be found in the work of McBain[186]) does not confirm the existence of adsorbed layers of a considerable thickness.

Experimental evidence supports the views of Langmuir, according to which only a single layer of molecules is oriented and strongly bonded to the surface. Under suitable conditions (for example, near the point of condensation, or in the case when there is a possibility of chemical combination) there may take place the formation of the two or more layers, but at a distance of several Angstrom units from the boundary line the surface already exerts no influence and the gas is "free."

Strengthening the Power of Adhesion

Having regard to the great importance of the adhesion factor in technology (to mention only aircraft plywood and laminates for building construction), it is well at this juncture to draw the attention of plastics technicians to a development which, so far, has not been sufficiently known.

This refers to the method for strengthening the adhesive power of a binding medium, as revealed by the work of Konstantinova[187] in Russia.

In 1933, Talmud[188] demonstrated that by introducing at the boundary interface between the two solid phases (between the surface of a crystal and the surface of a "glue"), an adsorption layer of a surface-active substance, or the "molecular solder," so to speak, it is possible to alter the surface energy at this boundary interface. In this way it is possible to influence and reinforce the strength of adherence.

Every process of adhesion consists, essentially, of the introduction of a fluid layer between the two solid surfaces, and hardening this layer within a certain interval of time. As a bonding medium, in most cases, serves a fine film of lyophile sol, which after gelation is converted into a solid gel. On drying, the strength of body thus formed is usually increased. As a cementing fluid can act not only a film derived from sol, but also film made by any fused material (viz., natural and synthetic resins, high

hydro-carbons, salts, etc.), which is capable of hardening on cooling, as well as the film of a liquid, hardenable as a result of chemical reactions, for instance, oxidation.

However, in all cases the gluing operation substantially depends upon the nature of the bonded surfaces, that is, whether they are porous, e.g., wood, or non-porous, hard and polished like the surface of metals, [189] etc.

In the event of joining porous surfaces, the adherence depends, in the main, on the penetration of a cementing substance into the pores. However, in the case of jointing the non-porous and highly polished surfaces, the principal factors determining the strength of the bond are the specific affinity of the surface to the cement film and the disruptive strength of this film after its hardening. This latter case is, clearly, of the greatest practical value to industry.

Thickness of Film and Strength of Joint

In this connection of special interest is the relationship, discovered by McBain,[190] between the thickness of the binding film interposed between nickel and aluminium surfaces and the strength of the joint. The reduction of the thickness of the cement film greatly raises the power of adhesion. This increase of adherence strength becomes noticeable at the film thickness of 1 mm. With the finest films the strength of bond can be augmented sevenfold. The increase of the adhesion power does not depend upon the form of the film used, that is, whether the binding medium between plates is introduced in a liquid or solid state.

The work of Hardy and Nottage[191] provides a curve diagram of the strength of adhesion in joining steel plates in relation to the thickness of cementing films. In this case the film thickness is determined by the force of compression of the plates during the cooling of the binder. The reinforcement, i.e., the increase of the adhesion power, begins only with the film thickness under 5 μ.

Besides these data, mention should be made of the connection between the strength of adhesion and the molecular weight of the cementing medium. Hardy and Nottage have found that for acids and paraffins, as binders, this relation is linear.

Constantinova's study is interesting in that it sets as its primary object the answer to the question of the influence of the adsorption layers ("molecular flux") upon the strength of the bond, when they are introduced between the surface to be joined and the surface of the gluing film.

The easiest way to detect the alterations of the surface energy at the boundary interface of the two solid phases is when one of the phases (cement), prior to hardening, has poor wetting property with respect to another. For this reason, paraffin was selected to function as the "glue," and the surfaces to be joined were those of crystals of quartz and calcite.

It has been observed that the adhesion strength of paraffin to the quartz is appreciably greater when a very thin, fine film of paraffin is interposed between the two quartz plates than the adherence of quartz to paraffin in a thick layer.

Results of Experiments

These experiments revealed the following interesting results:—

(a) the introduction of the monomolecular layer ("molecular flux") at the boundary interface between the two solid phases can considerably increase the adhesion strength of the bond;

(b) in the capacity of the "molecular flux" at the boundary interface of quartz and calcite with paraffin were applied various alcohols, acids and amines;

(c) as the molecular weight in the homological series of the "molecular fluxes" increases, the strength of the adhesive bond grows;

(d) the introduction of the "molecular flux" into the fine, thin layers of paraffin promotes an appreciable strengthening of the paraffin cement film.

Thus the assumption of inter-molecular forces of attraction leads us to the conclusion that all bodies, irrespective of their state of aggregation, must possess the property of internal friction. The latter factor is of special importance to the coating field, since this force, defined in terms of the coefficient of viscosity of the fluid, determines to a great extent the applicability of plastics as colloidal systems.

(To be continued.)

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STRAINERS FOR PIPE LINES

A Neat and Efficient Design

THE value of efficient strainers for pipe lines conveying steam, water and solutions in water, and fluids in general, to remove every trace of grit and general suspended solid material does not require emphasis, and in this connection much interest attaches to a neat and efficient design of strainer, made by Walker, Crosweller and Co., Ltd., Cheltenham (Glos). This is the "Arkon Type Y," in the form of a small fitting, generally screwed into the pipe line, having a protecting portion at the bottom, which contains a cylindrical screen, inclined at an angle, through which the steam or other fluid passes, whilst the separated solid particles fall to the bottom by gravity. From time to time the end cover is unscrewed and the screen taken out to remove the separated material. In general these strainers should be fitted in a downcoming or horizontal pipe to collect dirt and grit, and also with the cap downward.

Sizes are available to suit pipes within the range of ½-in.-8-in. diameter, constructed of gunmetal or malleable iron for 150 lb. pressure or of cast iron for 125 lb. pressure, whilst flange fitting in the pipe line can also be carried out as an alternative to the use of screw thread. The standard hole size for the screens is 1-64-in. diameter, whilst, as giving an indication of the small dimensions of the complete fitting, the ½-in. size malleable iron is 3¾-in. overall length, 1⅛-in. overall diameter and 2¾-in. overall depth. For the largest 1½-in. size the corresponding figures are 7⅜-in. length, 2⅝-in. diameter, and 5½-in. depth. Also the screens are usually of perforated phosphor-bronze metal sheet, but other materials are used as required, such as monel metal and stainless steel, whilst similarly, if desired, sizes of holes can be included from as low as 200 mesh screen to as large a ½-in. diameter.

Some typical specific applications in addition to those already indicated are Diesel oil and petrol, lubricating oil, cooling water for bearings and other purposes, including engine and refrigerator circulation systems, and in connection with air conditioning and general ventilation.

Du Pont Kapok Substitute

A new material called "Bubbifil," which consists of strands of viscose interspersed with air bubbles about ¼ in. long and which resembles a string of beads, has been developed by the Du Pont de Nemours Company as a substitute for two materials that were normally obtained from the Far East—kapok and sponge rubber.

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